AIR FORCE LEGENDS NUMBER 205

McDONNELL XF-88 VOODOO

BY STEVE PACE

ABOUT THE AUTHOR

A veteran writer, Steve Pace has authored 18 books and 18 articles dealing with a multitude of different aircraft - including airliner, light attack bombardment, heavy bombardment, cargo transport, experimental, fighter, fighter-bomber, fighter-interceptor, foreign, patrol bomber, prototype, research and service test types. Steve resides in Tacoma, Washington.

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BACK COVER:

Top, the XF-88B was a NACA project which converted the first XF-88 into a supersonic propeller test bed. The XF-88B takes off from the McDonnell factory on an early test flight. (McDonnell)

Bottom, the cannon armed XF-88A is in the foreground with the XF-88 flanking it in the background while at the McDonnell factory in February 1952. (McDonnell)

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FRONT COVER:

The XF-88A in flight near Lambert Field on 8 April 1950. (McDonnell via Robert F Dorr) The photograph was colorized by Hollywood Effects Artist Frank Savino. (Wave Form Effects, (323) 664-2571, savino@linkline.com)

McDONNELL XF-88A/B VOODOO

BACKGROUND

By the mid 1940s, gas turbine (turbojet) engine development had advanced to a point where turbojet power plant contractors coufd boast of lower engine dry weight and specific fuel consumption, higher sea level static thrust rating and engine-thrust-to-weight ratio. These claims created a great deal of optimism, and for the first time, that optimism overshadowed earlier pessimism. It was with this new belief in progress that the United States Army Air Forces (USAAF) was prompted to sire several new and important turbojet engine-powered fighter aircraft programs. One such program was its revised long-range bomber escort and strike fighter, which it now called the Penetration Fighter program.

The original long range bomber escort/strike fighter program spawned the Consolidated Vultee Aircraft (Convair) XP-81 "Silver Bullet" and the Bell Aircraft Corporation XP-83 "Airarattler" projects. These aircraft failed to offer enough of an improvement in performance to warrant replacing the World War Two piston engined fighters still in service. The USAAF's Penetration Fighter project was created in the hope that an airframe contractor could choose the proper engine and then design and develop a jet-powered, long-range bomber escort and strike fighter that would succeed where the XP-81 and XP-83 jet-powered entries had failed. It was to initially supplement and ultimately replace World War II era Lockheed P-38 Lightnings, Republic P-47 Thunderbolts and North American P-51 Mustangs.

On 28 August 1945, in its attempt to field a long-range bomber escort fighter to double as a ground attack aircraft, the USAAF's Air Materiel Command (AMC) released an Invitation to Bid (ITB) to the industry. With the ITB came a stringent list of Specific Operational Requirements (SOR). These included:

A single-place cockpit; bubble-type cockpit canopy

A twin-engine arrangement

Sweptback flying surfaces

Four-to-six 20-mm cannon armament with provision for external jettisonable external tanks and ordnance

600 mph maximum speed

Ten-minute time-to-climb to 35,000 feet; 40,000 ft service ceiling

900-statute mile combat radius with full combat load

Above, large conceptual model of the "V" tailed McDonnell Model 36C as seen on 9 August 1946. (Boeing)

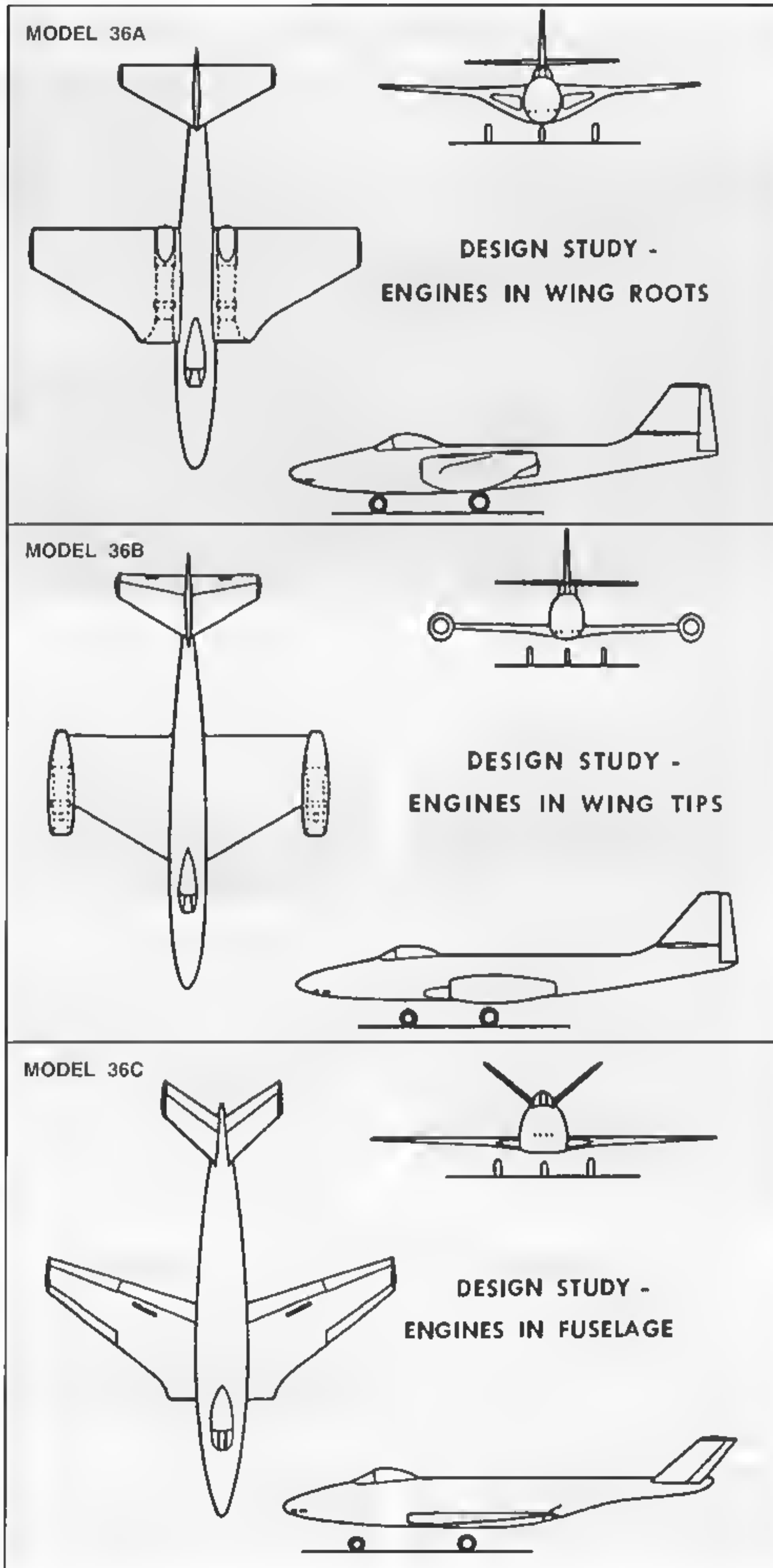
But even before the ink had dried on this list of requirements, a series of changes came about: combat range with full load of ordnance/external fuel was increased to 1,500 statute mi; then changed to 600 statute mi; service ceiling was upped to 50,000 ft; and time-to-climb was now five minutes - but to 50,000 ft.

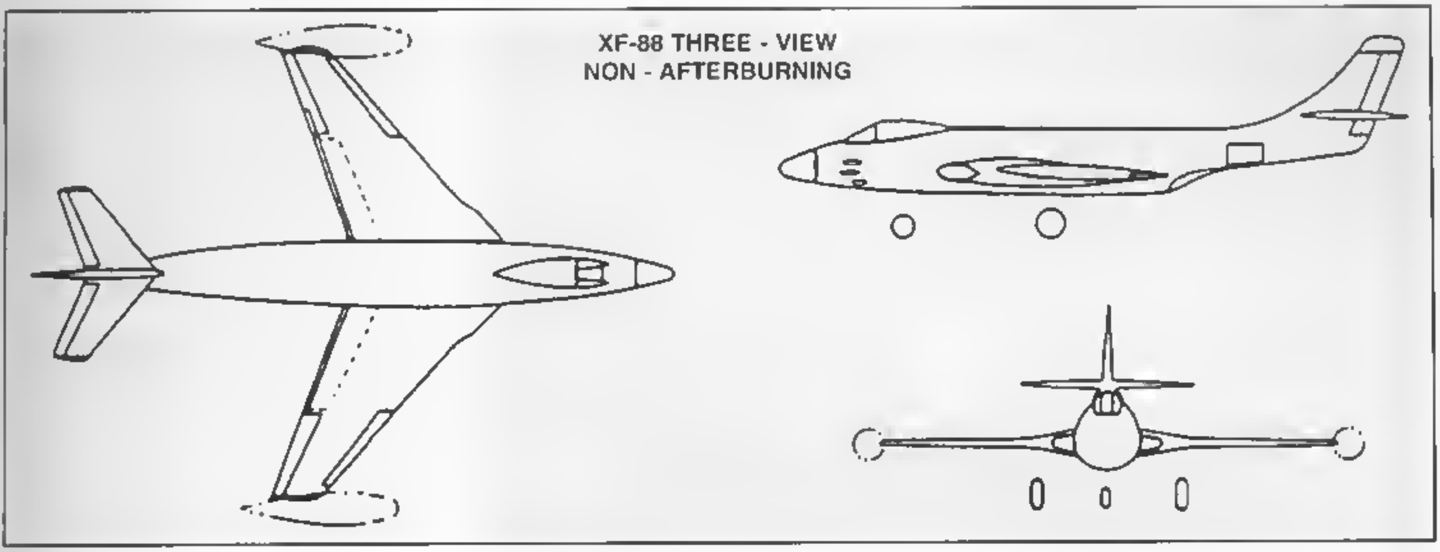
With these and other fluctuating requirements in hand, the McDonnell Aircraft Corporation (McAir) of St. Louis, Missouri, initiated its Model 36 Penetration Fighter project. McAir chief engineer Kendall Perkins (later vice president, engineering) selected E. M. "Bud" Flesh to serve as project engineer and Dave Lewis as chief of aerodynamics. Design work began, and before long, McAir came up with its Model 36A. Its design was based on McAir's XF2H-1 Banshee offering to the U.S. Navy and was not proceeded with. Next came the Model 36B, similar to 36A, but with little improvement. The third design, the first proposal actually submitted to the USAAF, was McAir Model 36C.

Above, McDonnell's chief engineer during the XF-88 Penetration Fighter Project was Kendall Perkins. He joined McAir in 1941, and first worked on the XP-67 "Moonbat", the first aircraft designed and built by the company, (Boeing)

On 13 October 1945 then, less than two months after it had received the ITB, McAir submitted its third Penetration Fighter concept to the AMC at Wright Army Air Field (AAF) in Dayton, Ohio. The Model 36C, as it was designated in-house, featured a "V" tail, or butterfly tail, arrangement similar to the twin tail arrangement

Below, the late Edward M. "Bud" Flesh, charged with the design and development of the XF-88, joined McAir in 1946 and soon became project engineer on the XF-88. (Boeing)





found on today's Lockheed Martin F-117A Nighthawk stealth fighter.

McDonnell Aircraft's proposed Model 36C Penetration Fighter was quite large and heavy for a single-seat fighter-type airplane, due to fuselage volume requirements for its twin-engine propulsion system, and adequate internal volume for fuel, which had dictated its size and weight. The former parameter was to provide space for its two axial-flow, 11 stage Model 24C-4 Westinghouse Electric J34-WE-13 turbojet engines, while the latter was to allow for an internal volume of 1,434 gallons of AN-F-48 100/130 octane fuel. Adequate space was also needed for the aircraft's AN/APG-5 (A-1 gun sight) radar ranging fire control system (later AN/APG-30) and six (as decided upon) M-24 electrically-fired 20-millimeter cannons with 220 rounds of 20-mm ammunition for each, not to mention cockpit area, radio equipment and so on.

The Westinghouse J34 turbojet engine, based on Westinghouse's earlier J30 and J32 axial-flow designs, held great growth potential in 1945 and a number of airframe contractors designed some of their aircraft around it. Moreover, Westinghouse was developing a pair of more powerful versions of the J34 - the Model 24C-8 (J40) and the Model 24C-10 (J46). In a prudent move, McAir designed its Model 36C to accept any pairing of these three engine types, which added to the need for the aircraft's large internal volume.

After a somewhat lengthy evaluation period, which lasted a little longer

Below, XF-88 number one, 46-525, during final construction with ship number two's fuselage visible beyond the partition, (McDonnell via Fred Roos)

than eight months, McAir was awarded a Letter of Contract (LC) on 20 June 1946 for engineering data, wind tunnel models, a full-scale engineering mockup, a static structural test article and two flyable aircraft (USAAF contract number W33-038-AC-14582). The mockup was to be ready for inspection by August 1946 and first flight was to occur in April 1948.

One flyable airplane was designated XP-88 and was issued USAAF serial number 46-525. The second airplane was designated XP-88A and received serial number 45-526. The XP-88 was to fly first without afterburner units for its two J34 turbojet engines; the XP-88A would be the afterburner-equipped engine test bed. At this time, the AMC stamped Secret Project MX-811 on McAir's Penetration Fighter program.

Of the eight Penetration Fighter proposals submitted, only two of them - McAir's and Lockheed's - held enough promise to achieve USAAF/AMC recognition. Thus, almost simultaneously, Lockheed Aircraft Corporation received an LC for two XP-90 aircraft; Secret Project MX-812.

The other six Penetration Fighter entries came from Curtiss-Wright, Consolidated - Vultee, Northrop, Goodyear, independent engineer John Abbeman, and a small engineering group called Management and Research. Oddly, a number of first-line companies - Boeing Airplane Company, Douglas Aircraft Corporation, North American Aviation and Republic Aircraft Corporation - choose not to submit any proposals.

McDonnell's XP-88/-88A mockup, given its 689 Engineering Board inspection during 21-23 August 1946, was approved. The result: McAir received a formal contract for its XP-88 and XP-88A aircraft on 14 February 1947. The USAF was most pleased with McAir's XF-88 airplane, especially with its overall effort to show its many suggested F-88 configurations - including a two-seat, all-weather (night) fighter-interceptor, and others. McDonnell demonstrated how its basic F-88 airframe, with a different nose section and so on, could easily be adapted to perform most any other mission requirement.

In the meantime, since the XP-88A was to have afterburner equipped engines, project engineer Bud Flesh went forward with afterburner development. He asked Westinghouse and several other powerplant contractors if they could produce a 52-inch long maximum length nonliquid-injection-type afterburner unit for J34 engine application to give the XP-88A better takeoff, climb and high-speed performance than the non-afterburner-equipped XP-88. The afterburner section could not be any longer than 52 inches due to the XP-88's takeoff rotation clearance parameters. He never received an adequate response. Therefore, McAir was forced to undertake its own in-

Below, the first XF-90 with its two jettisonable wing tip mounted external fuel tanks installed. With 667 gallons of extra fuel carried in the two tip tanks, the XF-90 carried a maximum of 1,665 gallons. McAir had a lot of trouble with the tip tanks on their XF-88. Whether Lockheed experienced similar problems remains unclear. (Lockheed)

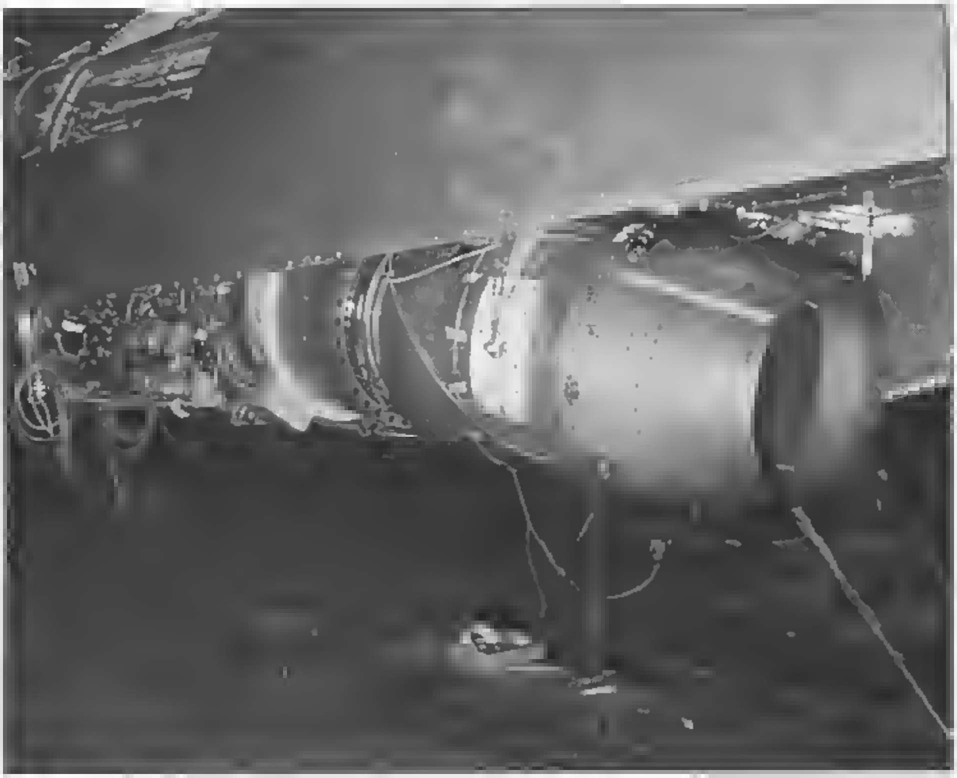
house afterburner development program for the J34 engine. This action created what was called the MAC Short afterburner, the acronym MAC meaning McDonnell Aircraft Corporation.

Since Lockheed had also selected the J34 turbojet engine for its Penetration Fighter entry, it had the same problem, in that the J34 without afterburning would only develop about 3,200-lb. thrust. But with afterburning, it was estimated, the J34's thrust output would increase to about 4,200-lb.; or, 8,400 total pounds thrust via two afterburning J34 engines in each airplane.

As an aside, on 18 September 1947 and 11 June 1948 respectively, the USAAF became the U.S. Air Force (USAF) and the P prefix for Pursuit was changed to F for Fighter.

Now complete, the first XF-88 was rolled out on 11 August 1948 at McAir's Lambert Field facility in St. Louis, Missouri. Emblazoned on its nose was the name Voodoo. It was subsequently delivered via truck to Muroc (now Edwards) Air Force Base in California where a series of preflight tests were conducted. These tests included engine runs, low-, medium- and high-speed taxi runs to make sure the aircraft's nose landing gear wheel steering, flying surfaces (ailerons, leading-edge flaps, trailing-edge flaps, rudder and elevators) and wheel brakes were up to par.

Then, under the guidance of McAir chief test pilot Robert M. "Bob" Edholm, the maiden flight of the non-afterburning XF-88 Voodoo occurred on 20 October 1948 - some six months late but still only 28 months after McAir received the go-ahead. As had been expected, with only a maximum of 6,400-lb. thrust from its two non-afterburning J34-WE-13 engines, Bob Edholm found the aircraft to be woefully underpowered. Further, he noted, even with the projected addition of 2,000-lb. thrust via the upcoming MAC Short afterburners, that the top speed of the aircraft would not go much above mach 1.0. Nevertheless, flight test activities continued.



Above, McAir-designed afterburner installation being fitted to the XF-88 in January 1949. (McDonnell via Fred Roos)

Below, "Bob" Edholm poses in his G-suit next to the XF-88 after its roll-out on 11 August 1948. Note rear-view mirrors mounted on the canopy frame. (Boeing)

XF-88 NUMBER ONE ROLLOUT ON 11 AUGUST 1948

XF-88 FIRST FLIGHT ON 20 OCTOBER 1948

Above, the XF-88 made its first flight more than seven months before the XF-90 and more than fifteen months before the YF-93A. (AFFTC/HO)

Below, the premier XF-88 poses on the ramp at Edwards AFB (then Muroc AFB) on 23 September 1948, nearly a month before its first flight. (AFFTC/HO) At right, two views of the non-afterburning XF-88 number one in March 1949. Note the smoothly blended exhaust pipe area on the aft fuselage. (Boeing) At right bottom, XF-88 above the Mojave desert. (AFFTC/HO)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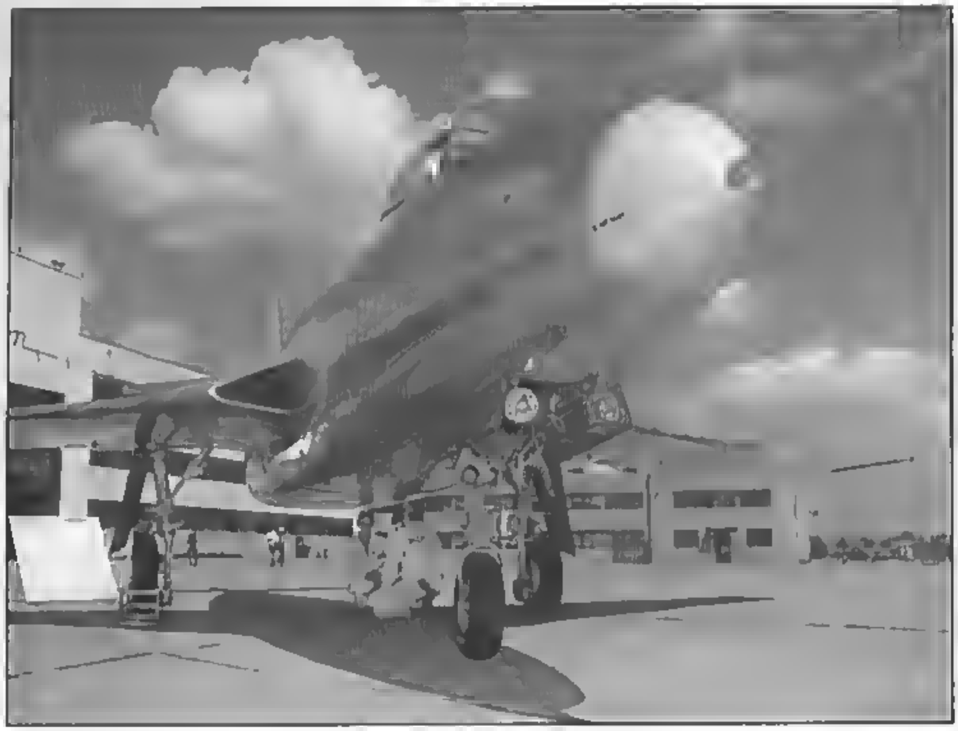


At left, the number one XF-88 shortly after roll out at St Louis. Note nose gear details and twin landing lights mounted on the nose gear doors. (McDonnell via Fred Roos)

DESIGN AND DEVELOPMENT OF THE XF-88 VOODOO SERIES OF AIRCRAFT

Kendall Perkins and E. M. Flesh presented a paper entitled Design and Development of the XF-88 on 17 July 1952 at the Confidential Design Session of the Annual Summer Meeting of the Institute of the Aeronautical Sciences in Los Angeles, California. In part, the paper reads as follows:

INTRODUCTION:

Although the studies leading to the design of the XF-88 were begun nearly seven years ago, the generally satisfactory performance of this airplane and its unusual freedom from difficulties uncovered in flight have taught us lessons in fighter design which we believe you will find of interest.

We try to follow the principle that we should deliberately choose when to be bold and when conservative. Boldness is called for in the design of major features where large performance gains are possible and where the state of the art is such that the inevitable troubles will not be too many or too hard to correct within a reasonable time. In all other cases a cautious policy is best for both major and minor elements of design. In fact, we believe that the more bold we are in one respect, the more conservative we must be in other respects to keep the amount of trouble down to manageable proportions. We particularly try to suppress innovations for the sake of academic curiosity.

In the XF-88 we were bold in designing wing/tail surfaces with sweep back and minimum thickness, irreversible powered flight controls, and our own afterburner. On the other hand, we chose a conservative size, location, and configuration for the tail, high lift devices, landing gear and for most of the other design characteristics.

TYPE REQUIREMENTS:

Work was initiated on the basis of informal Air Force requirements which called for a new type - a "Penetration Fighter" with a combat radius of at least 900 statute miles and fighter performance over the target good enough to cope with anticipated enemy opposition. These two requirements, one for long range and the other for high performance, were obviously in deep conflict and the combination tended to produce a machine heavier than we had learned to think fighters should be. There were other missions and other requirements, but the combat radius and performance as fighter, as limited by size, largely set the pattern. An upper limit of 15,000 pounds for combat gross weight was mentioned as a highly desirable, if somewhat wishfu,l objective.

EVOLUTION OF THE DESIGN:

MODEL 36A

One of our early solutions had a fuselage almost identical to that of the XF2H-1 Banshee which we had under development for the Navy. Other characteristics were also similar, including the use of two engines located in enlarged wing roots. The wings and tail were swept 20 degrees on the 40 percent chord line and were 6.5% thick. Wings were tapered 3.5 to one. This wing had a straight trailing edge, which we assumed would give effective ailerons and flaps, and the appearance suggested a conservative delta. This configuration had many advantages but was abandoned because we were not sure we could maintain good airflow over the wing roots at a sufficiently high speed. With engines inside the wing, the vertical distances from the [air] duct inlet to the upper and lower wing surfaces looked greater than the thickness of the wing farther outboard. For a greatly enlarged inner wing to have high speed characteristics as good as the outer wing, we felt that the thickness at the top and bottom of the inlet should be less than the thickness of the outer wing because, at inlet mass [air] flow ratios of less than one, these areas were, in effect, at an angle of attack different from that of the wing, and because little sweep effect could be counted on in this area. (Fig. 1A)

MODEL 36B

Another more radical attempt was made. Several advantages of this configuration were immediately apparent: 1. Engine accessibility and replaceability would be excellent; 2. [Air] inlets and inlet ducts would be very simple and inlet loss would be practically zero; 3. No [engine] exhaust extension [tailpipe] would be needed and the exhaust could not impinge on any part of the structure; 4. The effective [wing] span would be greater than the actual span from the standpoint of induced drag; and 5. Structure would be relatively simple and economical to build.

Disadvantages included the following: 1. In the event of an engine failure at low speed, such as soon after takeoff, the yawing moment would be too great to control with a vertical tail of reasonable size; 2. Good [air] flow at high speed would be very difficult to attain at the intersection of the wing and [engine] nacelle; 3. The high inertia about the longitudinal axis would make roll entry sluggish; and

4. The combination of three concentrated weights made up of the two power plants and the fuselage all joined together by a relatively thin and flexible wing suggested aeroelastic problems of alarming proportions.

In spite of its attractive features the disadvantages of this configuration were important enough to rule it out..

MODEL 36C

The Model 36C was the first Penetration Fighter proposal we submitted to the Air Force. Although the air inlets and the tail were later changed, this configuration was very similar to the final one built.

At about this time we were receiving microfilm reports of German research on the aerodynamics of swept [back] flying surfaces and had translated enough information to know of the effectiveness of large angles of sweep and to have gained confidence in the feasibility of designing swept surfaces. We analyzed these reports with avid interest and became convinced that an appreciable amount of this new data was so great that it was an ideal time to initiate the design of a new fighter for our Penetration Fighter program.

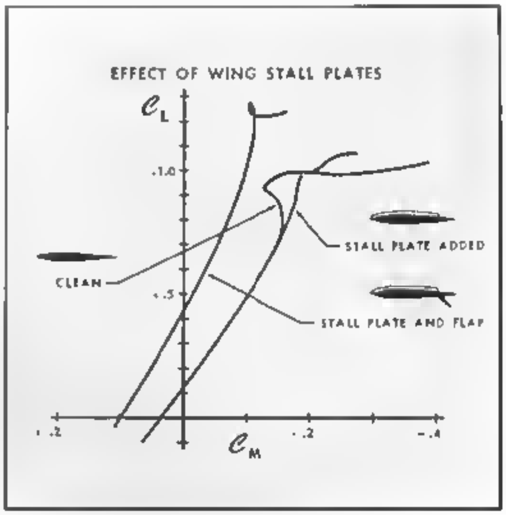
WINGS:

In Germany, more tests had been made at a sweep [back] angle of 35 degrees than at any other. To use less didn't offer much gain. To use more seemed almost foolhardy. So we chose a 35-deg. sweep at the 25% chord line. We later found that many others had made the same choice, presumably for much the same reasons.

In choosing the thickness of surfaces, we went a little farther than others. We made the wings and the horizontal and vertical tail surfaces all 7.9% thick as measured in an airfoil parallel to the airplane centerline. The decision to make the wings as thin as this was felt to be risky but not unduly so in this particular case, for two reasons: first, we used an unusually large taper [ratio], approximately 3.5:1, so that the absolute thickness of the inner wing was not abnormally small; and second, in the area where the wing was thickened near the fuselage, it had a greatly increased bending and torsional rigidity, thus compensating for a possible lack of rigidity in the remainder of the wing.
In choosing the airfoil we were looking for a maximum of laminar [air] flow at subsonic speeds and a minimum of pitching moment variation at transonic speeds. On this basis, we placed the airfoil perpendicular to the 25% chord line and used an un-cambered 65-009 section modified arbitrarily by making the trailing edge radius .015-in. one-quarter inch behind the 100% chord point, and then drawing straight lines from this new trailing edge tangent to the original airfoil at the 70% chord point. This is close to what is now known as the 65A-009 airfoil. Because of taper and sweep, the wing airfoil parallel to the airplane centerline has its 7.9% maximum thickness located at 44% of the chord.

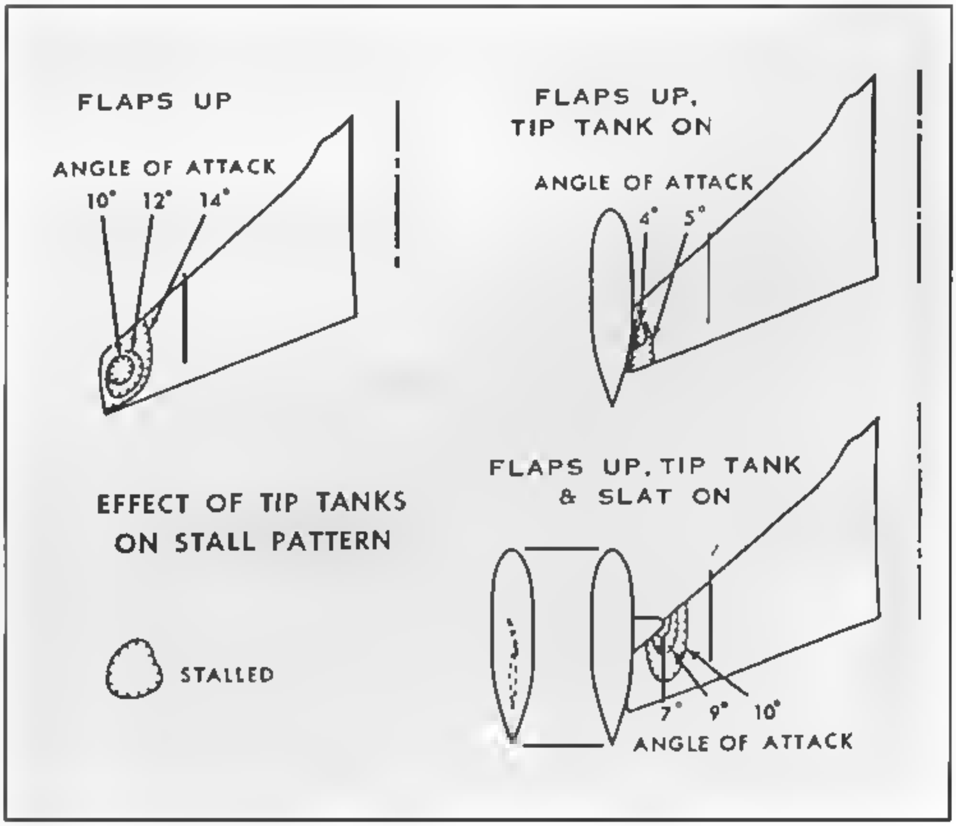
This wing was found at first to have undesirable longitudinal stability characteristics at high lift coefficients due to [wing] tip stalling. The figure above shows the beneficial effect of stall plates on pitching moment. These plates were located at 70% of the semi-span, ran from the leading edge to the aileron hinge on the upper surface, and were three-in. high.

Nose [leading edge] flaps of 13% chord were located in the outboard 36% of the semi-span and could be rotated downward 30-deg. Used in combination with conventional split trailing edge flaps of 45% semi-span, it was possible to get a maximum trimmed lift coefficient of 1.26. A higher coefficient could have been obtained at some sacrifice in pitching moment characteristics.

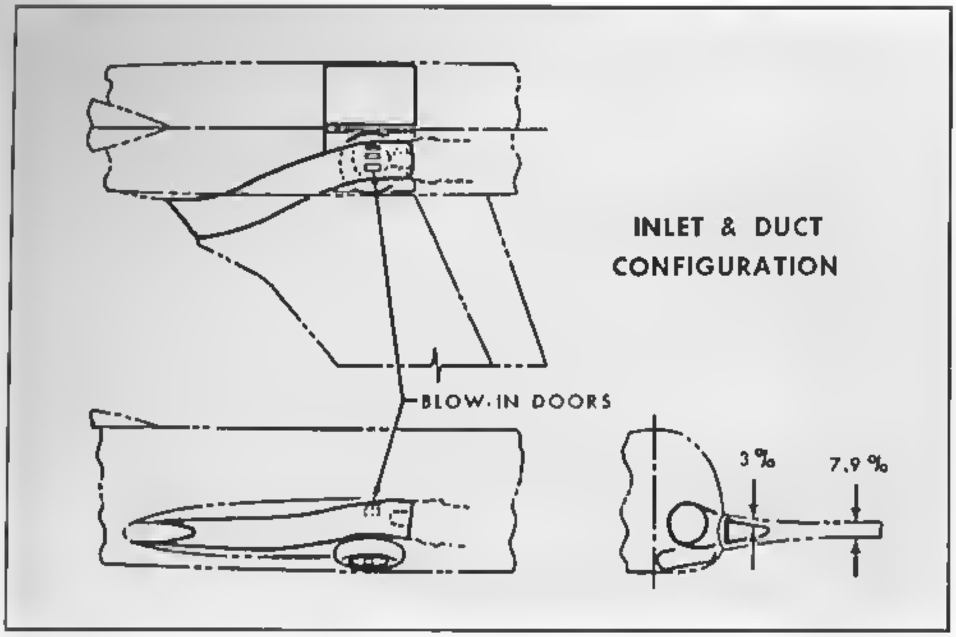


In checking the wing stall pattern in the wind tunnel with and without [external fuel] wingtip-mounted tanks we encountered a serious stall condition with tanks, on. This is shown in the figure below.

Many attempts were made to eliminate, or reduce, this tendency to stall too early at the wing-to-tank intersection. We tried various positions of the tank and a variety of fillets, vanes, stall plates and slats. One of the most effective efforts was a cambered slat of triangular planform cantilevered inboard from the tank ahead of and over the wing leading edge. This helped, but we were never able to



EFFECT OF TIP TANKS ON STALL PATTERN

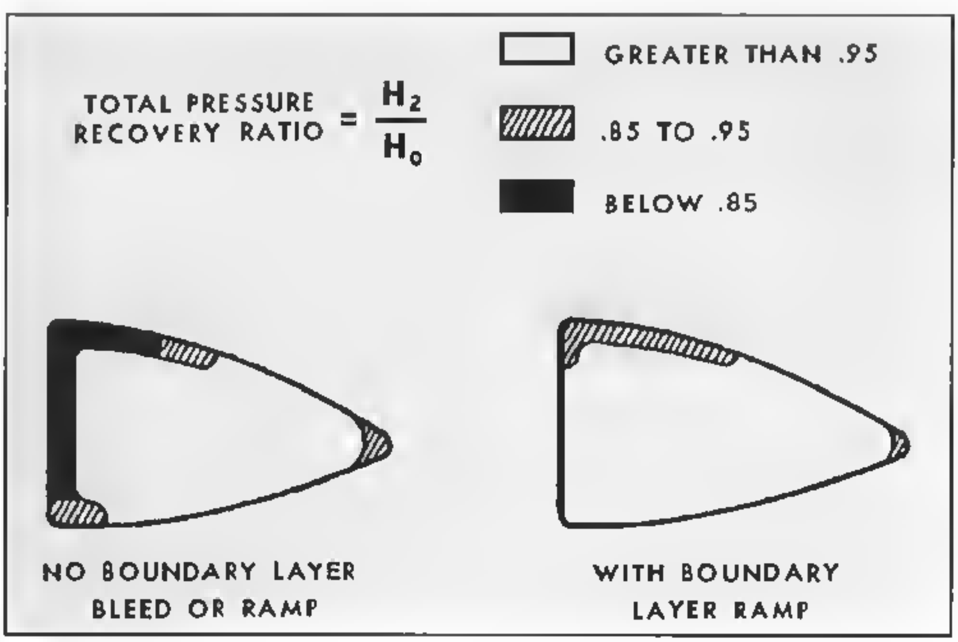


get a really satisfactory solufion to this problem.

ENGINE NUMBER AND TYPE:

Before starting the XF-88, our company had not yet built eny production [jet-powered] airplanes. We had built and flown the XFD-1 Phantom and were designing the XF2H-1 Banshee. These mechines were equipped with fwo turbojet engines located in enlarged wing roots with eir inlets in tho leading edge. We felt that the use of two engines was an asset worth reteining (as long as one engine could furnish enough thrust for cruising) because turbojet engines were at the time less reliable than reciprocating [piston] engines, becouse they efforded the pilot e better chance to fly home affer combaf, and because fuel consumption et a particular altitude could be improved by cruising on only one engine. (Author's note: McDonnell did go on to produce 60 production FH-1 Phantoms end e number of production F2H Banshees.)

The Westinghouse J34 engine was the only one evailable of a size suitable for a two-engine arrangement, and it was largely on this basis that the J34 wes chosen, in spite of the fact that this left us in the vulnerable position of having no elternate engine to fall back upon. We had more experience with this type than with eny other and felt we knew more about its idiosyncrasies, and it had a good ratio of fronfal area to thrust and good fuel consumption.



ENGINE LOCATION:

It was with considerable reluctance that we abandoned the idea of locating the engines in the wing roots as we had in previous models. This would have left more space inside the fuselage in that valuable area near to center of gravity where it is always badly needed, particularly for fuel. It would also have permitted a shorter and straighter [air] inlet duct with better pressure recovery, and an exhaust fairing which could be aerodynamically cleaner and more easily developed.

On the other hand, we felt that as limiting Mach numbers wero pushed higher and higher, we would soon be running into a limit as to how fast fhe thick wing roof section could be flown without compressibility troubles. Structural layouts elso showed that with this engine location and with e vory thin wing, it would heve been difficult to carry the spar and torque box strucfure past fhe engines. For these two reasons we put the engines inside the fuselege side by sido.

The engines were placed in the bottom of the fuselago because the engine accessories were on fhe boffom of fhe engine and could be more readily reached from underneath, and because the engines could be removed and installed from below by means of en engine dolly. Having located the engines as far forward as possiblo for reasons of balance, we could either let the exheust emerge from tho bottom of the fuselage, distorting the fuselage lines to match tho exhaust nozzle, or we could extend the exhaust pipes aft past the tail and fair the rear fuselage more cleanly. We chose the former because we felt it avoided the extra weight, thrust loss and temperature insulation problems associated with a long tail pipe extension.

Actually we did not evoid theso difficulties entirely. With [our own MAC Short] efterburners installed, we heve encountered temperatures up to 350 degrees F and pressure fluctuations of ebout 4 psi [pounds per square inch]. Although these conditions required insulation and structural reinforcement we believe fhe weight end thrust loss is less with this outlet location than with an outlet at the end of the fuselage.

AIR INLET AND DUCT:

Although the engines were not in the wing, it was decided that the inlets should remain in the leading edge, for the following reasons:

1. A single inlet in the fuselage nose would interfere with radar, controls and gun installations and would require a much longer air duct with more weight and more interference with access to equipment and structure.

2. With air inlets on each side of the cockpit, we were afraid we could not avoid entrance of too much low energy boundary layer air. We were more concerned with the effect of bad distribution at the engine compressor inlet on blade reliability than we were with good total pressure recovery, about which we knew very little.

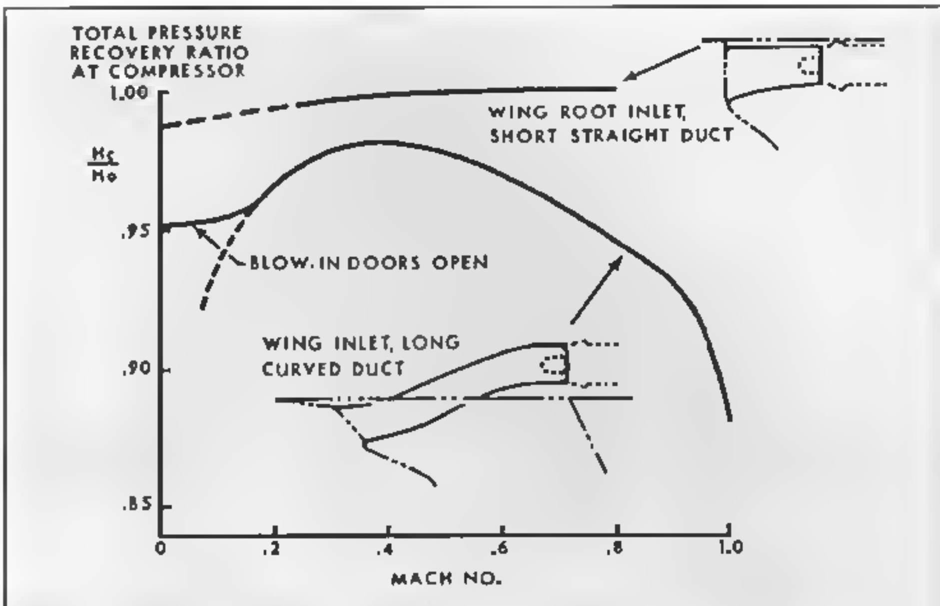
3. We had gotten excellent pressure recovery with wing inlets in previous airplanes and felt confident that good results could be obtained in spite of the double bend in the duct. We have since come to believe that adequate pressure recovery can be obtained with almost any reasonable inlet location, at least subsonically, and that results depend primarily on how well the detail development is carried out.

4. The thicker wing roots provided additional space near the center of gravity at less cost in terms of drag than if the equivalent space were provided in any other way.

5. There was a distinct structural advantage in having the thick wing root required with a leading edge inlet because of the greatly increased bending and torsional rigidity of this portion of the wing. Whereas this factor had been a minor one on previous models, it became important in this case because we were making the wing as thin as we dared.

You will have noticed that the air inlet first proposed to the Air Force was straight in plan view whereas in the final configuration the inlet lips were swept back 40 deg. This change was made to increase the critical speed of the lips and, somewhat to our surprise, there seemed to be no loss in inlet pressure recovery as a result. Modifications to the duct lips and various boundary layer bleeds and ramps were tested in the wind tunnel to increase the recovery at the inboard portion of the duct inlet. A two-inch high ramp was chosen as the best configuration and the pressure recovery inside the inlet lips before and after adding the ramp is illustrated on the bottom of page 10.

The ramp improved the pressure recovery, at least at subsonic speeds, to the point where very little of the area was less than .95.



PRESSURE RECOVERY AT COMPRESSOR INLET

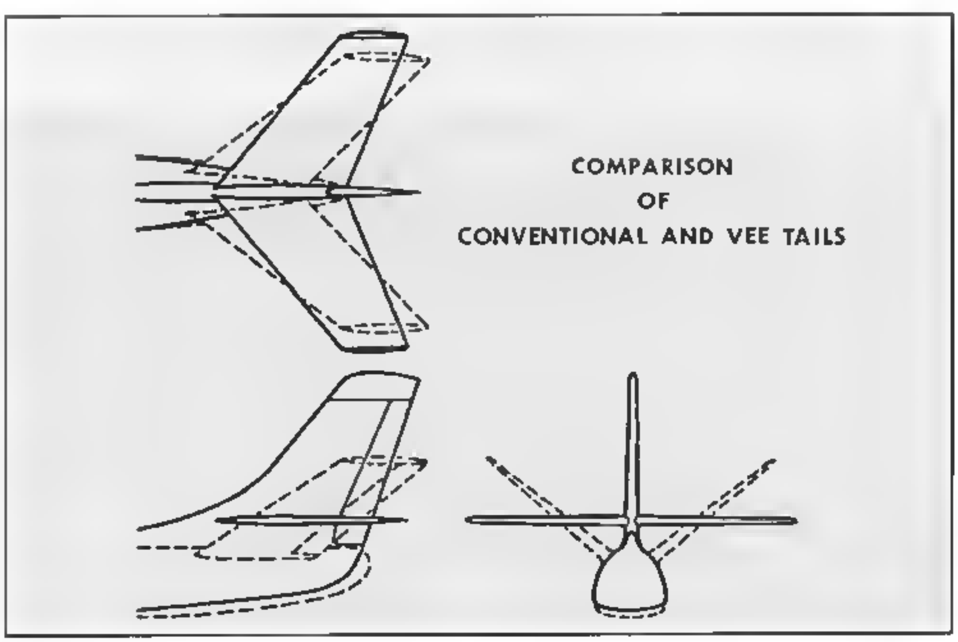
One obvious drawback of the arrangement joining an inlet in the wing with an engine in the fuselage is the double bend.

A one-half scale model of the engine air duct was tested statically, using a blower to pull air through the ducts at velocities corresponding to the full range of flight speeds. Several modifications were made to improve distribution over the compressor face. A turning vane was tried but did not offer enough improvement to be considered worthwhile. Although wing tunnel tests had been conducted to develop the shape of the duct lips, they were actually made of wood on the full scale XF-88 airplane in order to facilitate changes which were expected. Subsequent flight testing, however, verified the wind tunnel results so well that no changes were needed.

Illustration above shows the total pressure recovery at the compressor inlet of the XF-88 compared with the XF2H-1 Banshee, which had a duct both straight and short. At comparable speeds, the added curvature plus the added length are responsible for an increase in fuel consumption of about 8% and a similar loss in maximum thrust.

VERTICAL AND HORIZONTAL TAILPLANES:

The version first submitted to the Air Force [Model 36C] had a Vee tail with the idea of reducing the number [of tails] and improving the nature of tail intersections where compressibility effects were likely to give trouble. We did not expect to save



COMPARISON OF CONVENTIONAL AND VEE TAILS

At left, August 1950, unusual forward-opening speed brakes were a failure on the XF-88. Note main gear layout. (McDonnell via Fred Roos)

SPEED BRAKES:

Speed brakes were located on each side of the fuselage above and behind the engines. A comparison of power-off deceleration with speed brakes open and closed is given in the illustration at right.

In an attempt to get maximum drag and to minimize operating power we hinged the brakes at the rear and opened them through an angle of 65 deg. This arrangement is more effective than one with a forward hinge, but is not recommended for two reasons. First, we found it necessary to so completely perforate the brakes to minimize buffeting that the added effectiveness was lost. Second, there is some risk that if the hydraulic power should fail with the brakes open, they could not be closed.

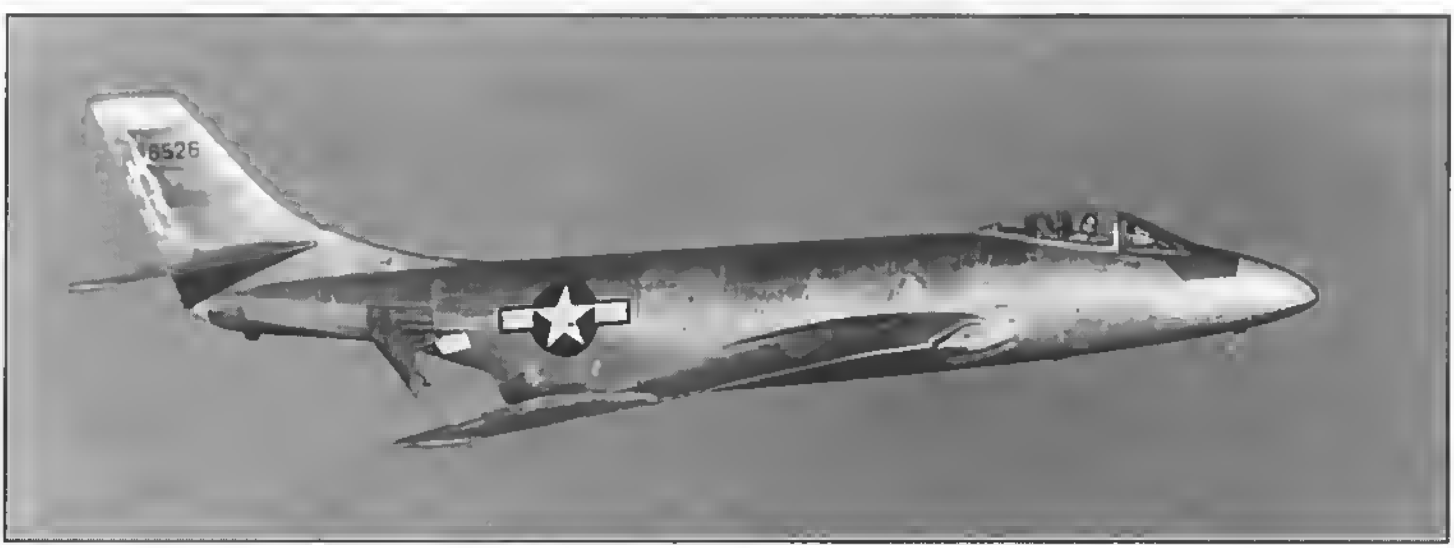
STRUCTURE AND AEROELASTIC PROBLEMS:

an appreciable amount of weight or low speed drag but did hope that a two-element tail would be simplor and cheaper to build than a three-element one.

Early in the wind tunnel tests, however, we encountered adverse rolling moments due to rudder action and insufficient longitudinal stability near the stall. A number of changes were tried in the wind tunnel but no combination of aroa [size] and dihedral [angle] was found which simultaneously gave good longitudinal and lateral stability characteristics, although they might have been marginally acceptable by employing elaborate mechanisms in the flight control system. A more conventional tail was therefore tested in the wind tunnel and, when it was found to be largely free of aerodynamic faults, it was chosen instead of the Vee tail.

In the tail surfacos the sweepback, thickness, and airfoil were made the same as in the wing. The horizontal tail volume was made .55 and the length 2.6 times the MAC [mean aerodynamic chord]. The vertical tail volume was made .086. The maximum thickness of the horizontal tail at the root was placed behind the maximum thickness of the dorsal [vertical] fin [tail]. There has been no trouble in flight which can be traced to compressibility effects at the tail intersection.

Below, XF-88, 6525, is shown on a 23 May 1950 test flight. Its unique and troublesome aft-hinged, forward-actuated speed brakes were being tested at the time. Both aircraft underwent speed brake door modifications whereby a series of holes had to be drilled through them to alleviate the excessive buffeting that was experienced prior to the modification. Note the small actuating arm door forward of the main speed brake cut-out. (McDonnell via Boeing)

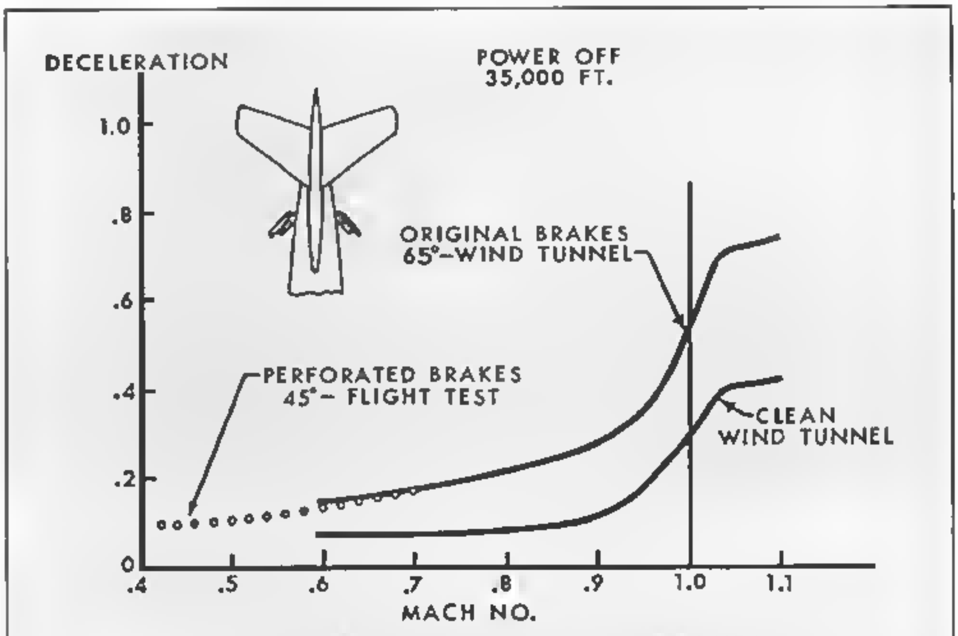


The structure of the XF-88 was designed for ultimate load factors of 11.0 positive and 4.5 negative G at the original design gross weight of 16,500 lbs.

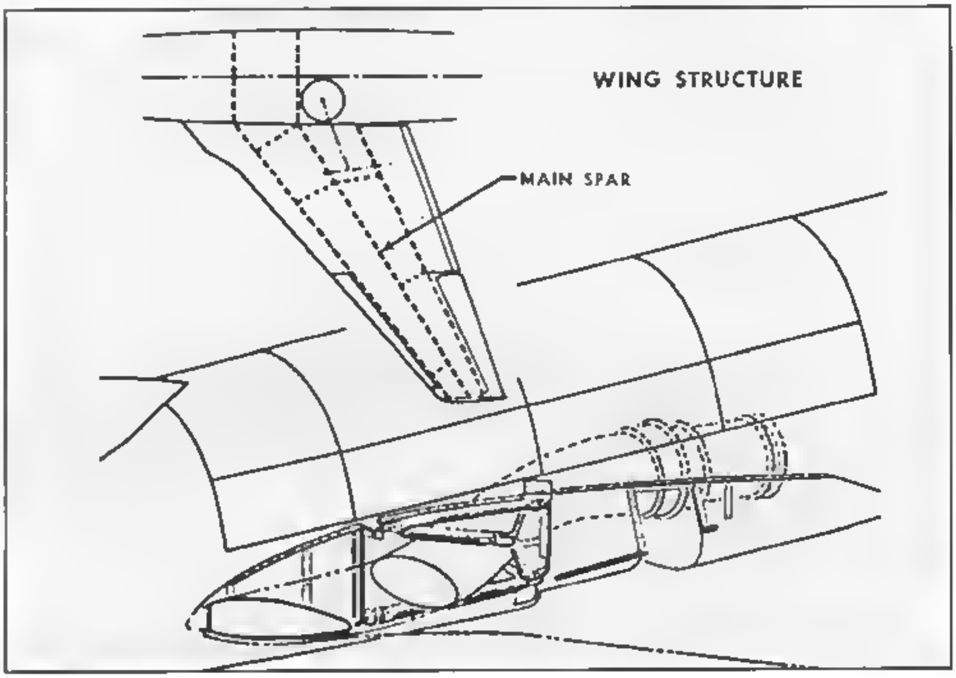
The wing incorporated one main spar located about at the maximum thickness which transferred essentially all of the bending into the fuselage, a front spar which acted as the torque box closure, and a rear spar for flap and aileron attachment. Wing torque was collected at a heavy rib at the fuselage side and transferred as a horizontal couple at the main spar attachment. A truss was needed to provide clearance for the engine air inlet ducts.

During the early stages of the wing design, calculations were made to check the loss in aileron effectiveness due to wing flexibility. The results indicated the possibility of aileron reversal in the vicinity of 0.85 Mn at altitudes below 10,000 ft. Though no flutter investigations had been completed at this time, it was expected that the wing also had inadequate margin of safety against flutter. The torsional rigidity of the wing was therefore increased by about 60% over that required by strength considerations only, primarily by increasing skin gage [thickness], although the weight penalty was nearly 200 lbs.

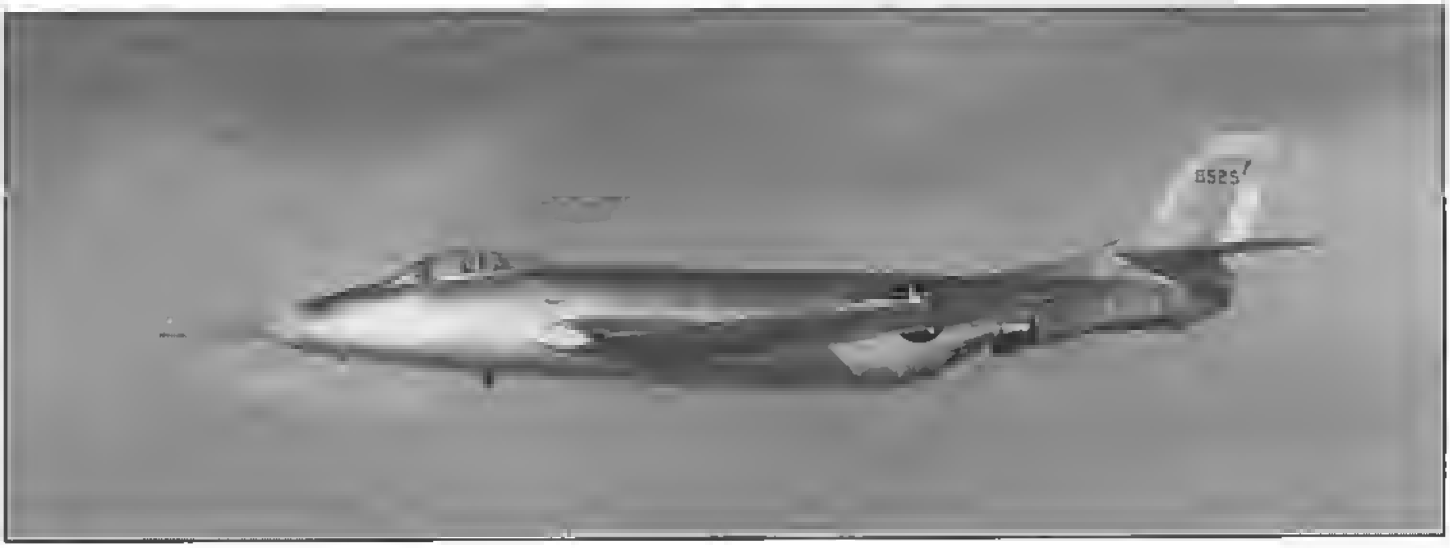
The flutter analysis of the airplane later showed clearly that the increase in torsional rigidity, incorporated to improve rolling effectiveness, was also essential from the flutter standpoint. Other than this, these studies predicted that the air-

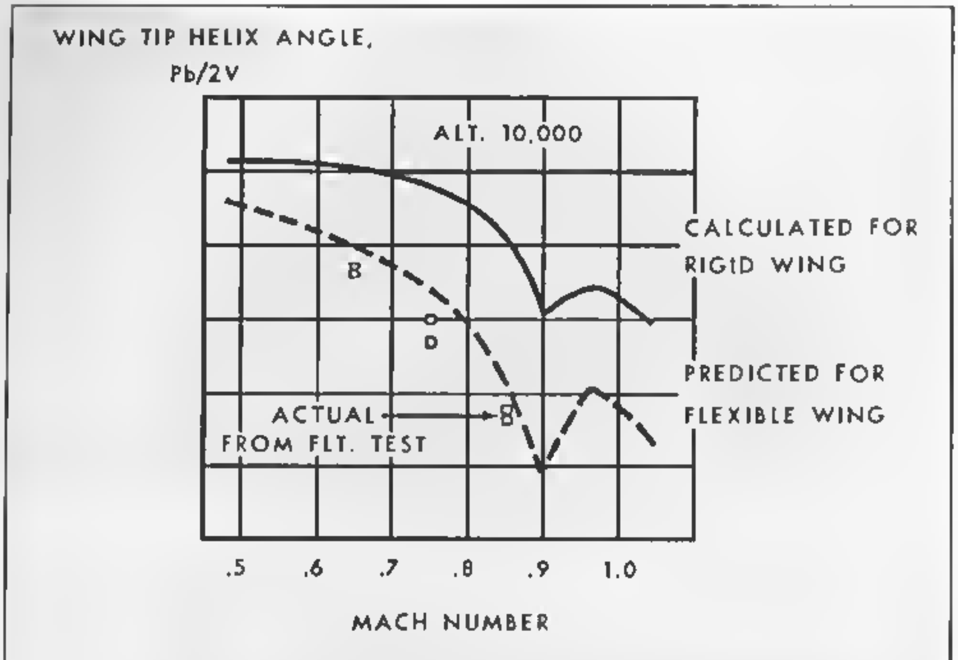


DECELERATION WITH SPEED BRAKES



Below, 6525 during speed brake tests over Edwards AFB (Muroc) in March 1949. (McDonnell via Fred Roos)





ROLL PERFORMANCE vs. MACH NO.

plane would be free from flutter difficulties, and none have been encountered.

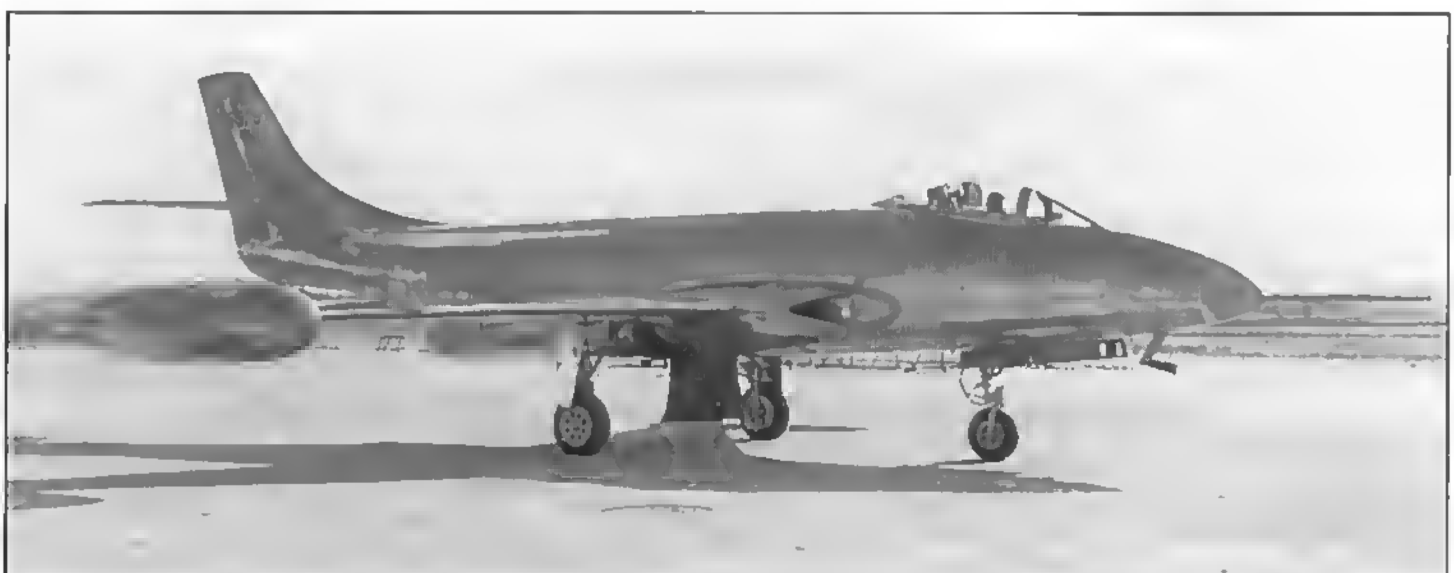
The illustration above presents a comparison of the rolling effectiveness of the ailerons as calculated with and without allowance for flexibility and as measured in flight.

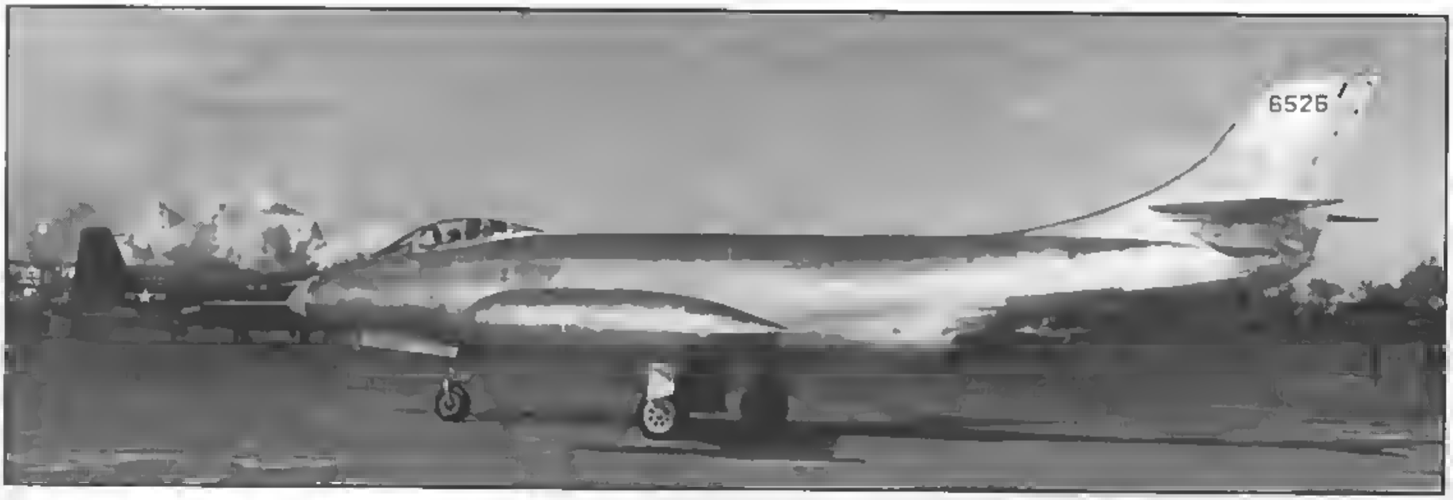
The results of a similar investigation of flutter stability with externally mounted 350-gallon wingtip fuel tanks was less satisfactory. The fore and aft shift in the center of gravily [CG] end the wide variation in the pitching moment of inertia of the fuel were shown to have a predominant influence on the dynamic characteristics of the wing. Analysis revealed that the critical flulter speed of the wing for many of the assumed tip lank configurations was wilhin the normal opereling speed range of the XF-88. The stabilizing influence of shifting the tank forward was also investigated. Unfortunately, where this was carried far enough to stabilize the symmetrical mode of flutter motion, the asymmetrical mode became critical. These results demonstrated to our satisfaction thet edequate stability for all of the configurations of the lip tank fuef could not be produced by this sort of modification and no other method of assuring adequate stability for all fuel quantities and airplane attitudes was found.

Ground vibration tests on the wing to confirm theoretical free-vibration characteristics showed graphically how the 350-gal tip tanks altered the wing dynamic characteristics. Observing the wing vibrating in the fundemental bending mode at a frequency of about 100 cycles per minute (compared with about 400 cycles per minute without tip tanks) was convincing evidence of the predominant influence of such a large [wing] tip mass. A considerable amplitude could be developed by merely pushing up and down by hand on the nose of the tank and it was obvious that a small input of energy in flighl mighl have disaslrous results. It was concluded that it would be impracticable from a flutter and deflection standpoint to Install such lerge tip tanks on an airplane with swept wings thin enough to fly at high speeds.

The vertical and horizontal stabilizer slructures were designed lwice. The first design was conventional with two spars and many ribs. The second consisted of six spars with ribs only at the root, tip and semi-span and thick, magnesium skin. The multi-spar stabilizer was chosen because it reduced the number of parts, reduced the weight, and increased the stiffness by several fimes. The stabilizer was fixed and torque loads were carried directly from stebilizer skin to fin skin through the fillet, making a further contribution to rigidity. The effect of stabilizer

Below, rare view of XF-88 number two with its 350 gallon wing tip fuel tenks installed. The first Voodoo carried 734 gallons of fuel internally, and with another 700 gallons externally, the eirplane would have 1,434 total gallons. (McDonnell via Robert F. Dorr)





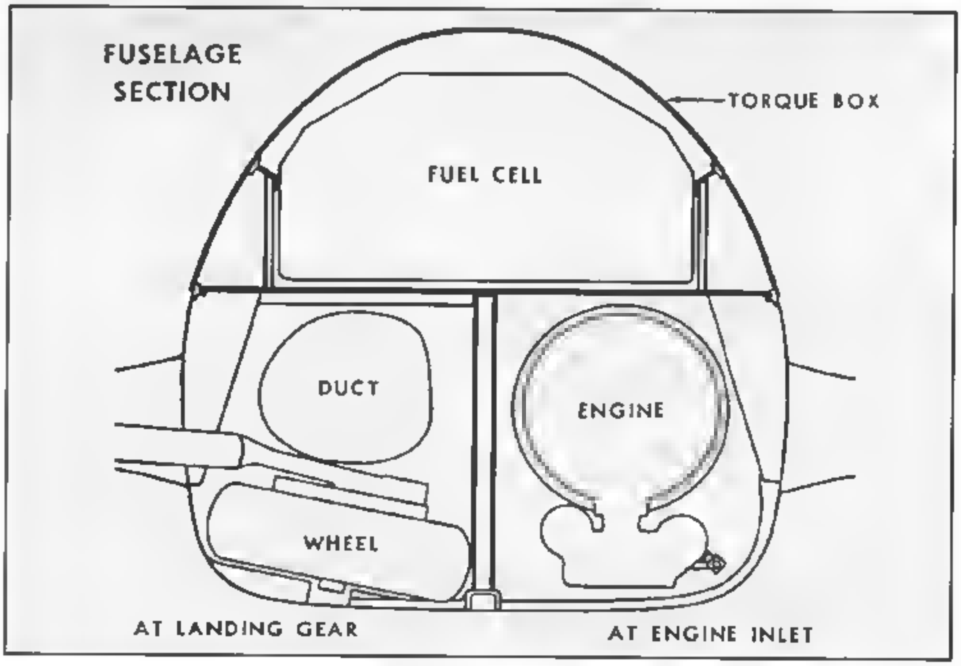
rigidity on longitudinal control effectiveness at high speeds was not fully appreciated at the time, but subsequent studies have shown that rigidity makes a tremendous difference in ability to pull high G load factors at high speeds.

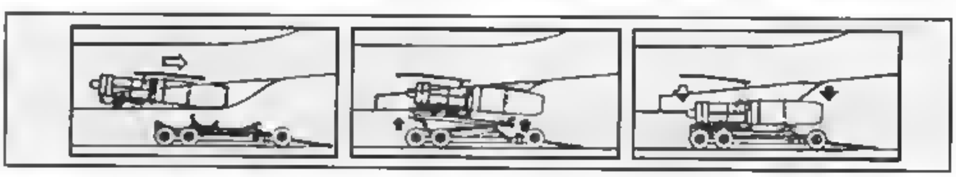
The torque box is confined to the upper portion which contains the fuel tanks. A central keel member between the engines assists in carrying vertical bending, and large non-structural hinged doors were provided for access to the engines.

POWERPLANT:

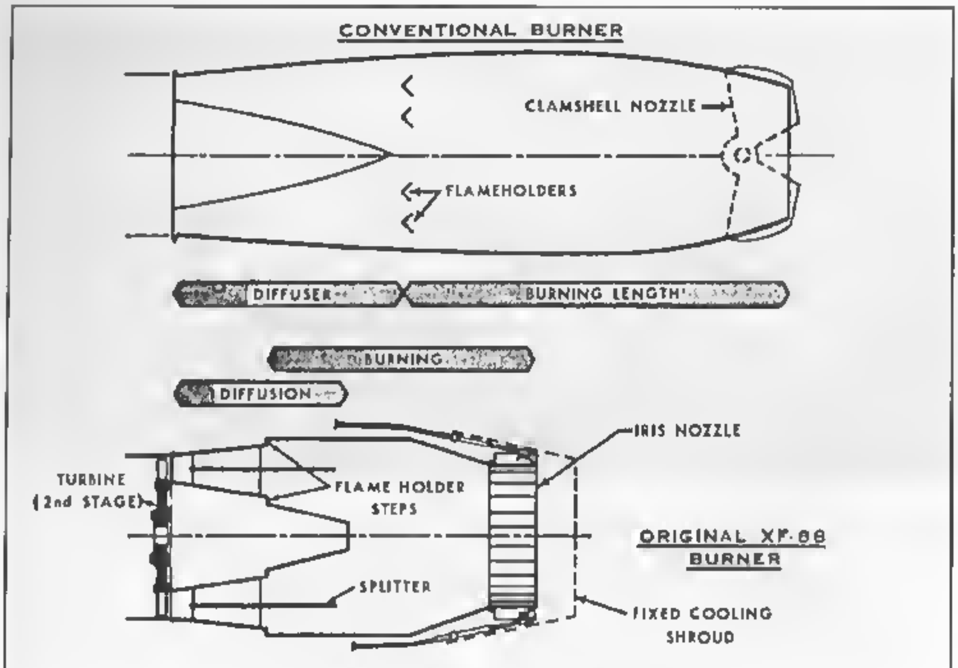
Engine accessibility and ease of removal were given particular attention. Engine removal is shown at right.

Three mounting points are released by quick-opening fittings and the engine is then hung from a roller operating on a





At top and below, two additional views of 6526 during tip tank tests. (McDonnell via Fred Roos)



AFTERBURNER LENGTH COMPARISON

track built into the fuselage. The engine can be rolled backward on this track to clear ell structure, at which point a standard bomb dolly Is raised to support the engine. It has been demonstrated that an engine can be removed and replaced in 23 minutes starting with a completely buttoned up airplane.

AFTERBURNERS:

A year or more efter the project had begun, we realized the need for, and the possibility of, getting better takeoff, climb and high speed performance with engine thrust augmentation such as some form of liquid injection or afterburning. It was concluded that afterburning would be more edvantageous than liquid injection, at least as applied to this particular airplane. Accordingly, we approached several engine and component manufacturers with a proposel that they develop an afterburner suitable for the J34 engine as installed in the XF-88. We specified that the maximum length be not more than 52 inches since the airplane configuration, which was solidly frozen at the time, did not provide enough ground clearance [tor takeoff rotation] tor more. At that time Banshees were being built for the Navy and similar performance gains might be made in these with J34 afterburners having a similar length limitation. It was found, however, that all manufacturers approached telt either that there was an inadequate market for another afterburner or that performance would be unsatisfactory because of the unusually restrictive length requirement.

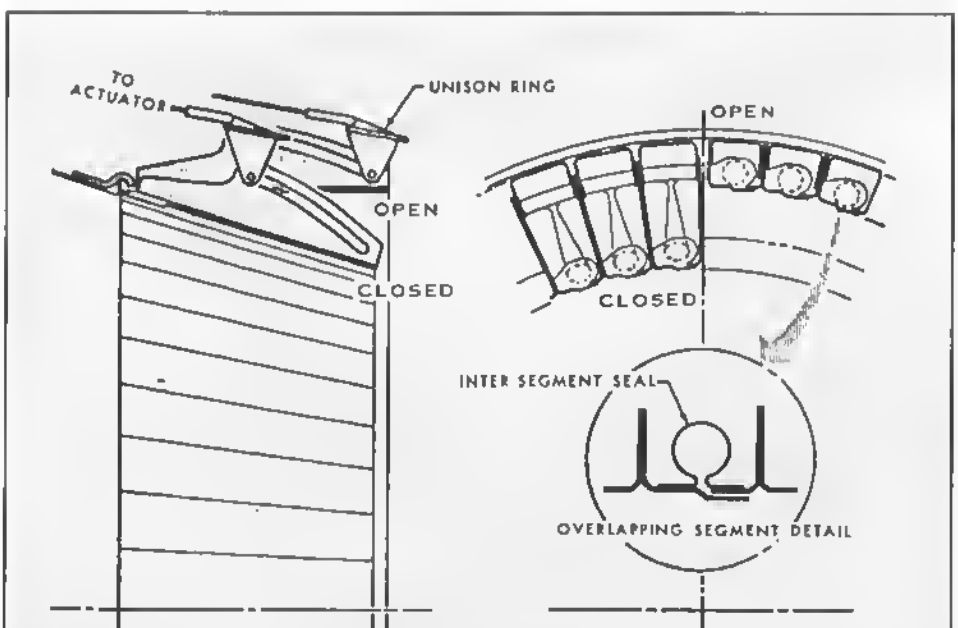
We probably would have abandoned the idea of installing an afterburner at that point except for the fact that we had been doing some combustion work of our own in connection with ram jets and pulse jets for helicopters, and felt that we might be eble to essume the responsibility ourselves. We had come across several ideas which might make possible reasonably good combustion efficiency within a small space and, et the same time, have a minimum of internal drag.

We do not think it is particulerly eppropriate for en airframe manufacturer to design and build afterburner units, but experience with the overall installation makes an airframe manufacturer more conscious than others of certain important requirements such as smooth oxternal airflow with all positions ot the [exhaust] nozzle. Our experience has been that realization of the importance of certain basic installation requirements is of great advantage in designing equipment of this kind.

We hed no test facilities of our own but were ablo to arrange for testing at the engine manufacturer's [Westinghouse Electric] plant and in a Banshee in flight. We felt justified in this case in flying with a minimum of prior ground testing because wo were using a two-engine airplane and could first install the afterburner on one side only, so that if it should fail, the pilot could still get home with reasonable safety.

Less than 14 hours of afterburning had been accumulated on the test stand before we first flew the efterburner, and no troubles appeared in flight to indicate a need for more ground testing. There are actually a number of advantages in getting into the air early with a device of this kind because the development of characteristics related to altitude end speed, such as blowout and light off, can be much more rapid with the aid of flight tests.

In developing this afterburner, we had five objectives: short length, good combustion efficiency, low internal drag or cold loss,



IRIS NOZZLE DESIGN

low external drag, and high nozzle efficiency. These were accomplished primarily through two innovations. First, a unique combination diffuser and flame holder, and second, an iris nozzle.

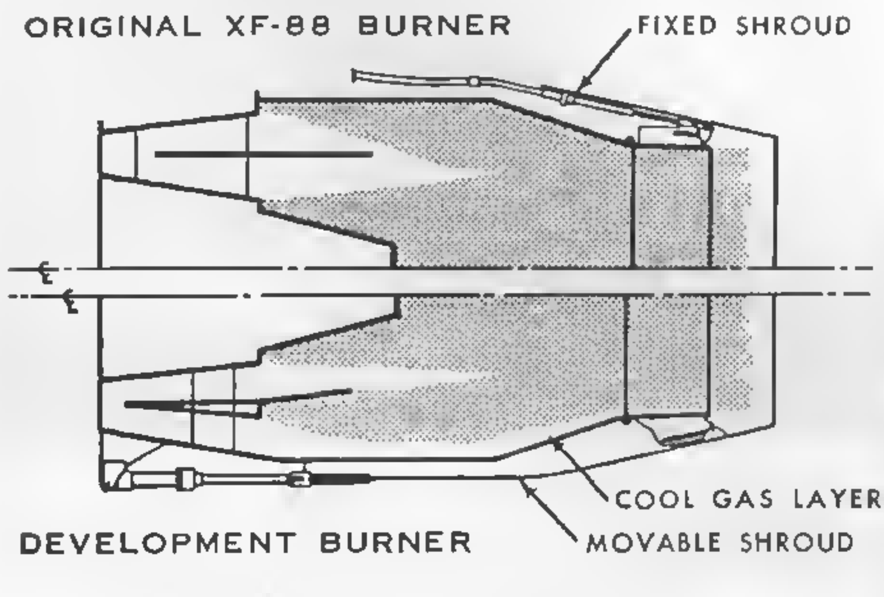
These were incorporated in our first burner design, as shown at left top, along with a typical conventional burner for comparison. You will note that the combination diffuser-flameholder arrangement accounts for a large part of the reduction in length. The diffuser was designed with a splitter and was fitted with steps designed to create local flame-holding areas of turbulent flow separation, with minimum sacrifice of diffuser efficiency. We felt that such a flame-holder, if it would work, would permit a lower cold loss than any of the more conventional types, most of which have flame-holders so unclean as to make some of us cringe, having been brought up to think that the drag of an exposed rivet head is an unwarranted inefficiency.

This afterburner also incorporated the first iris, or multiple-element nozzle, successfully used with a turbojet engine. As far as we know it is the only variable nozzle design which combines the features of continuously-variable circular exit and zero leakage. Operation is shown at bottom left.

In spite of its obvious advantages, many of us were at first less than enthusiastic about the iris arrangement because of the multiplicity of parts. Since we could find no other means of even approximating these advantages with simple mechanism, we went ahead with it and after design refinement it turned out to be surprisingly trouble-free and not unduly expensive.

Leakage was eliminated by means of overlapping segments and inter-segment seals. The area was varied by moving a unison ring forward or aft to actuate the cams of the hinged segments. During the nozzle development, many minor design changes were made in the segments and seals, and the unison ring was incorporated into a movable cooling shroud, but the original concept has remained much the same as shown at above right.

The flame-holder also required some refinement to achieve the best distribution, and particularly to provide that the layer of gas coming into contact with the nozzle segments was appreciably cooler than the remainder. This latter objective was accomplished by moving the outer flame-holder step from the outer shell to the splitter. With this type of flame-holder, we have gotten combustion efficiencies closely comparable to those of longer, conventional burners.

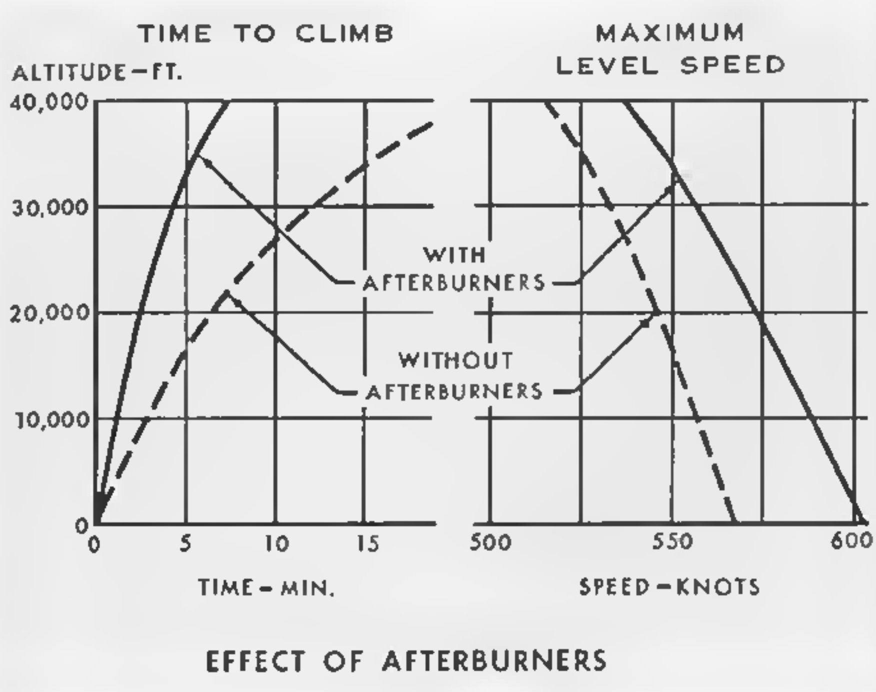


AFTERBURNER DEVELOPMENT

The first Banshee afterburner flights were made with rudimentary manual controls, but within a few months, it became clear that completely automatic control should be attempted. We used modifications of equipment on hand to pre-schedule afterburner fuel flow as a function of airflow, and varied the nozzle area automatically to maintain constant turbine outlet temperature.

The original control proved to be reliable and was used in many afterburning flights without significant malfunction. Since then, the control has been revised and refined considerably, but the same overall principle is still being used.

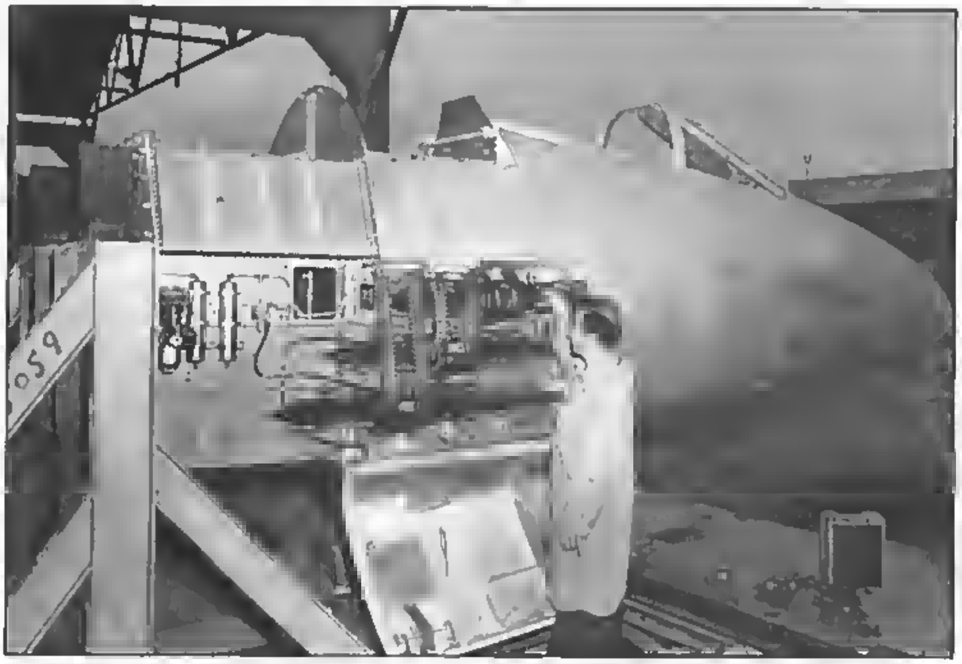
Later improvements in the nozzle have been directed toward a type in which both the inner nozzle and the cooling shroud exit diameters can be varied together. This should eliminate a large share of the base [boat tail] drag, which has an important effect on airplane performance.



EFFECT OF AFTERBURNERS

Above, number two XF-88 during an engine test using water-cooled mufflers. (McDonnell via Fred Roos)

Below, McAir technician works on 20mm live-firing forward gun test nose jig. (McDonnell via Robert F. Dorr) Bottom, nighttime gunfire testing. (McDonnell via Fred Roos)



The combination of the step diffuser/flame-holder with the iris nozzle, together with the control, enabled us to install afterburners which had the following characteristics:

1. Static thrust augmentation of 34%.

2. Specific fuel consumption of 2.52 lbs/hr/lb. [pounds per hour per pound] of thrust.

3. An increase in J34 engine length of only 30 in.

4. A unit weight of 218 lbs. including both cooling shroud and radiation shield, but without controls which weighed 80 lbs.

5. A cold loss of less than two percent.

6. Ability to ignite up to at least 44,000 ft. and burn to 51,000 ft. or more.

7. Completely automatic control.

The use of afterburners improved the speed and climb performance as shown at the bottom of page 17.

In addition, the takeoff run was reduced by 20% and range and endurance at low altitudes could be improved by using the variable nozzle to achieve more nearly optimum cruising conditions - without afterburning.

ARMAMENT:

Six 20-mm M-24 electrically fired cannons were installed, together with large capacity for 220 rounds of ammunition per cannon. In order to avoid the weight and handling difficulties with separate ammunition boxes of this size, we built the boxes integral with the structure and developed an electrically-operated loading device for feeding the ammunition belts from a ground cart backward through the ammunition belt feed chutes into the boxes. Using this device, it was demonstrated that two men could reload all six boxes and prepare all six cannons for firing in 12 minutes. Other armament included provisions for carrying eight 5-in. diameter high-velocity aerial rockets [HVAR] and the usual assortment of bombs and other external stores.

FLIGHT CONTROL SYSTEM:

The XF-88 was one of the first fighters to employ completely irreversible power controls with a system for artificially providing control force feel.

The system used a hydraulic power cylin-

der to actuate each of the three primary control surfaces and since the power control cylinders were irreversible, no forces due to air loads on the surfaces were felt by the pilot. The artificial feel system feature, which was incorporated into all three controls, was tied into the linkage between the cockpit and the power cylinders to provide the pilot with force reactions which kept him informed of the loads being applied to the control surfaces.

The artificial feel system was made up of a bellows containing a diaphragm subjected to dynamic pressure on one side and static pressure on the other. The dead center linkage, through which the bellows forces acted so designed that the variation of control force with control surface deflection was similar to that of a conventional system. An electric actuator which could be controlled by the pilot was placed between the feel system linkage and the control linkage to trim out any unwanted force. On the aileron and rudder, the addition of a centering spring helped to mask a friction dead band near neutral position. On the elevator, a bungee spring applying a force in the down elevator direction was incorporated to increase the apparent stick force stability at low speeds. This artificial stability proved to be quite acceptable to the pilots.

This is a conventional cylinder except that the piston contains the servo valve, hydraulically balanced and manually controlled to cause the piston to follow the movements of the valve end. A failure of the hydraulic system automatically permitted the fluid to by-pass so that the pilot retained direct control and could fly the airplane manually at reduced speed. This type of cylinder has been found particularly satisfactory because it has negligible lag.

We found it desirable to establish quantitative design limits for all-important char-

Above, 6526 during live-fire 5" High Velocity Aerial Rockets (HVAR) from its underwing stations. The aircraft was fitted with provisions for eight of these weapons. (Boeing)

Below, 6526 during armament tests in the spring of 1950 at Edwards AFB while carrying eight 5" rockets and two 1,000 pound bombs. The rockets were mounted vertically in pairs. (McDonnell via Robert F. Door)

acteristics of the flight control system. The most difficult to meet were the limits on friction with power-on, particularly in the case of the ailerons. Only after a great many months of laboratory effort were we able to get aileron friction down to two pounds of the control stick.

The decision to incorporate completely irreversible power controls was one of the best decisions made, since it enabled us to go through the complete flight test program, including supersonic flight to 1.175 Mn, with negligible controls alteration. No changes in any of the flight control surfaces were needed to meet force requirements and, after relatively few adjustments to links and springs, control forces were considered good. At the same time considerably more control power was available than if we had depended on manual controls in conjunction with aerodynamic balance.

Another advantage of irreversible power controls is that they automatically hold the surfaces rigidly and assist in preventing buzz, jab and other types of objectionable oscillation so often encountered at high speed. We haven't been courageous enough to eliminate mass balances. As speeds continue to increase, we suspect that every increment of additional rigidity we can get will prove desirable.

Of course, irreversible controls cannot eliminate buffeting forced by unstable airflow. They do, however, hold to a minimum the motion induced by buffeting and prevent the loads from reaching the pilot through the control system. This masking effect introduces a new hazard since structural loads due to buffeting can reach dangerous proportions without warning the pilot. For this reason, we installed strain gauges to indicate the magnitude of buffet loads during certain flights.

Power controls with artificial feel are admittedly complicated and, like most complicated devices, cost a considerable amount of weight and money. They also require extra maintenance and offer new sources of design and service trouble. However, if airplanes designed to fly supersonically are required to have great maneuverability and to meet rigorous control force limits, we feel that such a system is essential, and that equally good maneuverability and control forces cannot be developed with reasonable time and effort by any other means.

AUTOMATIC STABILIZATION:

Early in the flight test program [late 1948 and early 1949], we encountered inadequately damped directional oscillations together with objectionable roll coupling. We were unable to find any practicable change in aerodynamic configuration sufficient to correct this condition and were forced to the conclusion that some artificial means of stabilization would be essential. We were anxious to get an answer promptly and decided that rather than attack the yaw, the roll, and the roll coupling one at a time, we would attack them all simultaneously. Accordingly we installed four different types of dampers. It was found that a yaw damper using a yaw rate gyro and controlling the rudder gave the most satisfactory results.

Such devices have since become fairly common. In the XF-88 the servomotor was mechanically connected to the rudder through the power cylinder in such a way that when the motor is stationary, the normal control system operates the power control in the usual manner. When the normal system is stationary, the servomotor can oscillate the rudder without feeding motion back to the rudder pedals.

In the test installation, the pilot could choose any one of a number of gain settings and at any given airspeed and altitude, could obtain complete damping. Unfortunately no single gain gave the desired amount of damping at all airspeeds and altitudes, and it was necessary to add an airspeed switch to automatically change from one setting to another at 400 knots indicated airspeed. Without the yaw damper, the airplane feels uncomfortable to the pilots and certain kinds of targets would be difficult to hit because of directional oscillation. With the damper, the airplane is comfortable to fly and there is no question of its solidity as a gun-firing platform. The cost is high in terms of complication but seems inevitable.

FLIGHT TESTING:

Tests revealed that thrust was low during takeoff because of choking in the air duct. The air inlet area, although satisfactory for high-speed flight, was inadequate for static operation, taxiing and takeoff speeds. A section of air duct in the main landing gear wheel well was therefore rebuilt incorporating a number of spring loaded blow-in doors designed to open inward when the relative internal pressure was negative and remain open until the aircraft attained such forward speed that the duct pressure changed from negative to positive. These doors increased pressure recovery at zero speed by about 14% at the engine compressor inlet.

Tests to explore high Mach number characteristics were carried out cautiously inasmuch as wind tunnel results had indicated a slight tendency to "tuck under" and we had no accurate idea of where transonic speed buffet might be encountered.

Over a period of several months, nearly every flight was made at a slightly higher Mn. The highest speed attained was during the maneuver shown in the diagram at right.

This dive began at an altitude of 41,000 feet at 0.82 Mn with a split S. The pilot pulled at least 2 g during the entire dive and in the recovery pulled up to 3.4 g. Although airspeed indicators could not be relied upon, the maximum rate of descent indicated by the altimeter was 67,600 feet per minute. This corresponds to a Mn between 1.15 and 1.20 based on careful temperature corrections. At no time during this dive did any adverse trim change show up, nor was there any evidence of buffet, flutter or weaving. [This was flight number 70 of the number one XF-88.]
Longitudinal stability proved to be adequate, both stick free and stick fixed, through the center of gravity range from 22% to 32% MAC. The stall characteristics turned out to be better than expected. A slight buffeting occurred approximately 10 kias above the stall and when stall occurred, it was surprisingly gentle. A very high angle of attack was reached in a complete stall but there was no sudden change in flight path, the elevator control was positive throughout, and it was not difficult to hold the wings level.

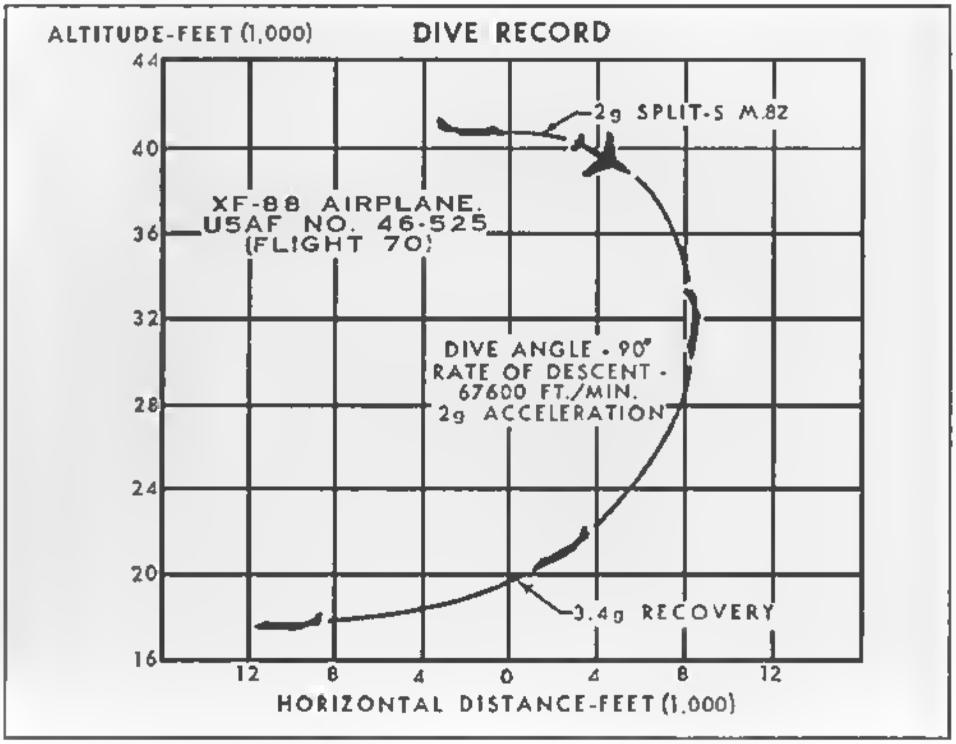
Rolling power was not as good as we would have liked. We tried increasing the aileron chord by 26% but found that this increased the roll helix angle by only 10%, indicating the need for still further increase in torsional rigidity of the wing.

A lateral re-trim condition was recorded at Mach numbers between 0.92 and 0.95 on the first airplane and between 0.95 and 0.98 on the other. In accelerating and decelerating through this speed range, the pilot usually, although not always, had to use about one-third of maximum aileron throw to keep the wings level. This condition is apparently due to a very small difference in the incidence and airfoil contour on the right and left sides such that separation occurs on one wing slightly sooner than on the other. It is undoubtedly aggravated by the fact that the aileron effectiveness is at its worst near this speed range. We don't know any feasible way to entirely eliminate this condition but believe it can be somewhat improved by

controlling with great care, the airfoil contours and incidence of the wings during manufacture.

We found the dihedral effect to be greater than we had experienced previously, and in consequence the airplane did not feel normal at high angles of attack to pilots used to flying straight wing machines. This effect has not proved to be a handicap in this airplane, although the problem might have been serious if more sweep back had been used.

It was found that the speed brakes, as originally designed, created excessive buffeting near maximum dive speed when fully opened. However, they were made acceptable from the standpoint of effectiveness and buffeting by perforating the speed brake doors with 3/4" diameter holes, cutting out 29% of the outer surface, and reducing the maximum opening from 65 degrees to 45 deg.



WEIGHT:

A summary of the weight growth of this airplane may be of interest.

Early estimates indicated a design gross weight for combat of 16,500 lbs., and an alternative gross weight for takeoff on a 900-mi. combat mission of 22,000 lbs. As design progressed, it became apparent that these estimates were optimistic.

The total increase, amounting to 22%, seems excessive when compared with many previous fighters, but is felt to be typical of most of those developed in the time period when structural configurations, maximum speeds, and equipment requirements were being changed so radically in comparison with previous practice. In our case, the greater part of the growth, other than due to afterburners, could be charged to insufficient allowance in the weight estimate for the following factors:

1. Structure needed to carry the loads from swept surfaces into and through the fuselage.

2. Structure needed to withstand higher dynamic pressures than previously encountered.

3. Structure needed to provide enough rigidity in unusually thin flying surfaces.

4. More than the usual sacrifice of structural efficiency to permit improved maintainability.

5. The introduction of new features such as power controls and the yaw damper.

6. Overweight of government furnished equipment.

In addition to the weight growth from inception to flight, this airplane, like most other military aircraft developed during the same period, has suffered from equipmentitus. It was heavily laden with a wide variety of equipment - electrical, electronic, hydraulic, pneumatic and mechanical, each item of which could be shown to be well worth while by a protagonist who was a specialist in his particular field. Unfortunately, the cumulative weight of hundreds of such items, plus the weight of the source required to furnish power for them, plus the weight of structure to support them, plus the weight of fuel to supply the additional engine power to carry the added weight, plus the weight of the larger wing and tail needed to meet stall speed requirements with the added fuel and equipment, plus the weight of the larger engine needed to keep performance up in spite of the added weight and wing area, all added up to an accumulation of weight written into original and subsequent requirements which groew at an alarming rate. Much of this is the inevitable penalty for progress. It will still take a great deal of vigilance, however, to keep this trend from seriously throttling our military efforts. There are many evidences of a realization of this problem in the Armed Services, and it is hoped that effective steps to solve it will be worked out.

The final configurations were: XF-88 (Model 36D)- sans later installation of afterburners, XF-88A (Model 36E) - afterburner equiped number two aircraft and XF-88B (Model 36J) aircraft with nose mounted turbo-prop.

CONCLUSIONS:

Some of the lessons we have learned while working on this project are summarized as follows:

1. Wings as thin as 7.9% can be used in a fighter with a 35-deg. sweep back without excessive weight or other penalty, if the actual thickness of the inner portion of the wing is made great enough.

2. Large tip tanks should not be installed on the tips of thin swept wings.

3. It is difficult to comply with longitudinal and lateral stability and control requirements with a Vee tail.

4. Material in the wing and tail structure of high-speed aircraft should be so distributed that the maximum possible percentage of it contributes to torsional rigidity.

5. Airfoil contours and wing incidence should be held to closer limits of accuracy than in the past, in order to minimize lateral re-trim.

6. Efficient afterburners can be built quite short by means of a step diffuser/flame-holder and they can con-

Above, test pilot Bob Edholm is greeted by chief engineer Kendall Perkins and program manager Bud Flesh as he climbs out of XF-88 number one at Lambert Field following its 100th test hop. Total hours after this flight was 88 as painted on the fuselage side. Among the standing XF-88 program dignitaries, third from left, is Mr. MAC, James S. McDonnell, founder of McAir in 1939. (McDonnell via Robert F. Dorr)

Below, XF-88 number one is in the foreground flanked by the cannon armed XF-88A in front of the McAir factory. (Boeing)

tribute materially to fighter performance without adding undue weight.

7. A continuously-variable exhaust nozzle for engines or afterburners, reasonably clean both internally and externally, can be built without undue weight or complication.

8. Irreversible power controls with artificial feel are necessary to supply adequate control power and to comply with control force requirements within a reasonable development time.

9. Automatic yaw stabilization is necessary in a fighter similar to the XF-88 to keep the airplane comfortably flyable and permit accurate gun firing against all kinds of targets.

XF-88 DEVELOPMENTS

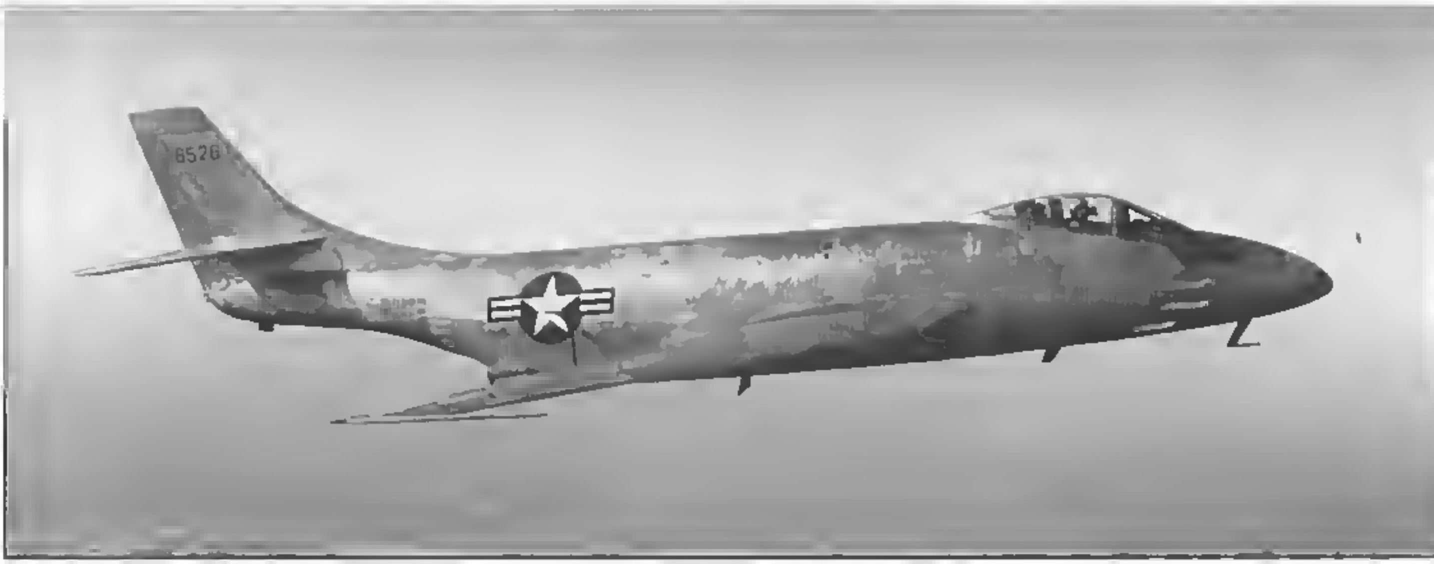
After McDonnell had completed its Phase I flight testing obligation, the USAF took over for Phase II. It proceeded to fly the non-afterburning XF-88 airplane 17 times during 15-26 March 1949 to accumulate 17 hours and 57 minutes flying time; about one hour per flight average. But it too found the XF-88 Voodoo underpowered - yet, very easy to fly and quite maneuverable.

The number two airplane, designated XF-88A with its pair of J34-WE-15 engines (without MAC Short afterburners being installed as yet) and other changes, rolled-out on 1 April 1949. It made its first flight at Lambert Field on 26 April, and among its several refinements, it featured a variable geometry (all movable) horizontal tail called a stabilator (combined stabilizer and elevator) and was armed with six 20 mm M-24 cannons; number one was never fitted with cannons. Both aircraft performed almost trouble free. However, number two was forced to survive two minor crash landings.

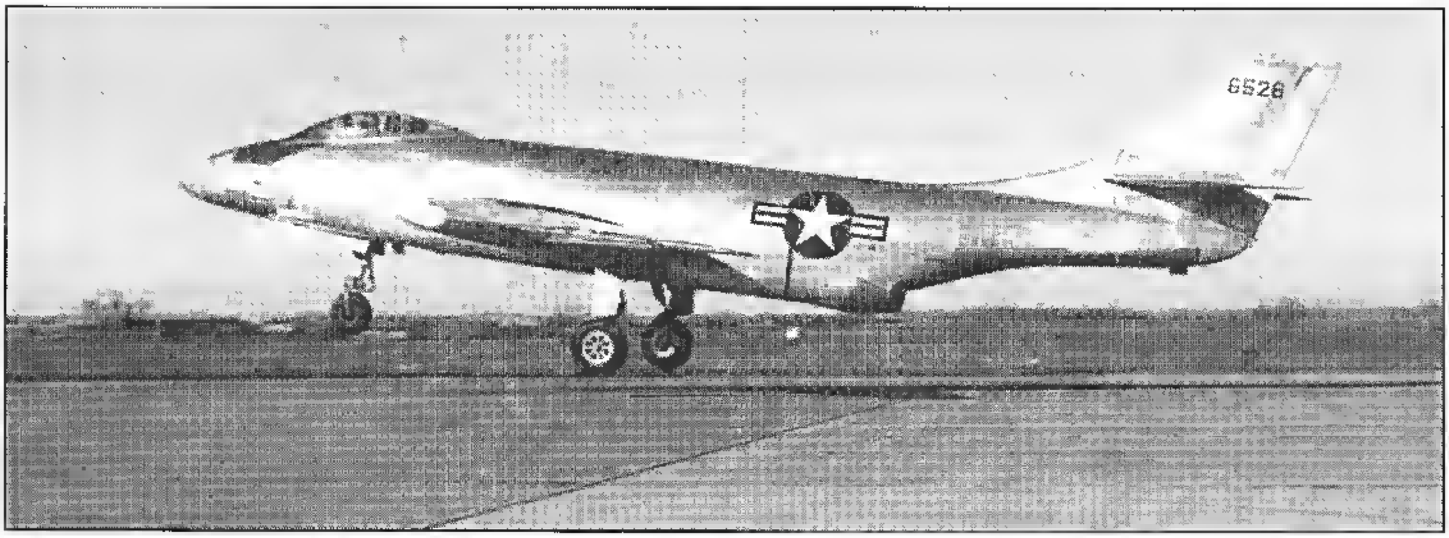
As previously mentioned, during the 70th test hop of XF-88 number one on 12 May 1949, Bob Edholm took it up to an altitude of 41,000 ft. and leveled off for an all-out assault on supersonic speed. Powered by its two non-afterburning J34-WE-13 engines, beginning at 0.82 Mach, Edholm entered into a full 90 deg. nose-down split S dive. As he passed through 32,000 ft., a top speed of 1.175 Mach was recorded. After pulling out of his dive at 17,000 ft., he safely landed, and became an early member of the then exclusive Mach One Club. Edholm noted soon after the flight that when the airplane entered into the transonic speed regime, through the supersonic speed regime, and back to subsonic speed, that it did not buffet. The flight had been smooth throughout, and the plane's aerodynamics was exceptional.

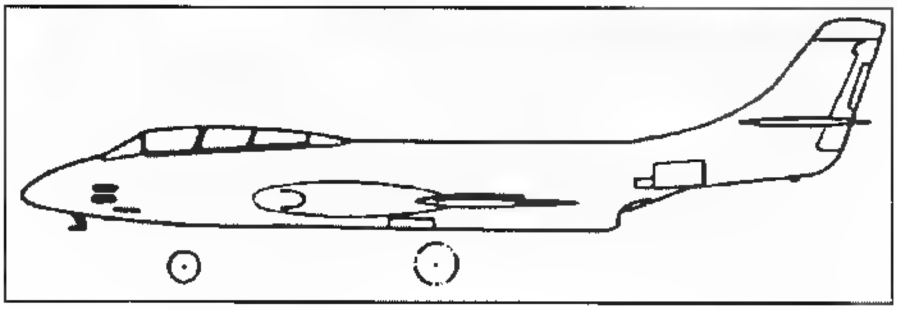
The XF-88 6525 poses with its cannon-armed brother, XF-88A 6526, in February 1952. (via Robert F. Dorr and McDonnell)

NUMBER TWO VOODOO, XF-88A 6526



The number two Voodoo was the first XF-88 equipped with afterburning engines and was designated XF-88A. It made its first afterburner flight with only the left-hand afterburner installed on 9 June 1949. It can also be distinguished from the number one bird by its six-gun nose and all-moving tail. The anti-glare panel forward of the cockpit also differed on the two aircraft. At left, three photos of the XF-88A supposedly taken during its first flight with both afterburners installed. Above and below, XF-88A on a test hop near Lambert Field on 8 April 1950. Forward opening perforated speed brakes are extended in the photo above. This aircraft would be used as a test bed for the McDonnell F-101A Voodoo program. Note the pitot tube was nose-mounted on an underbelly mast just aft of the radome. (McDonnell and Boeing via Robert F Door and Fred Roos)

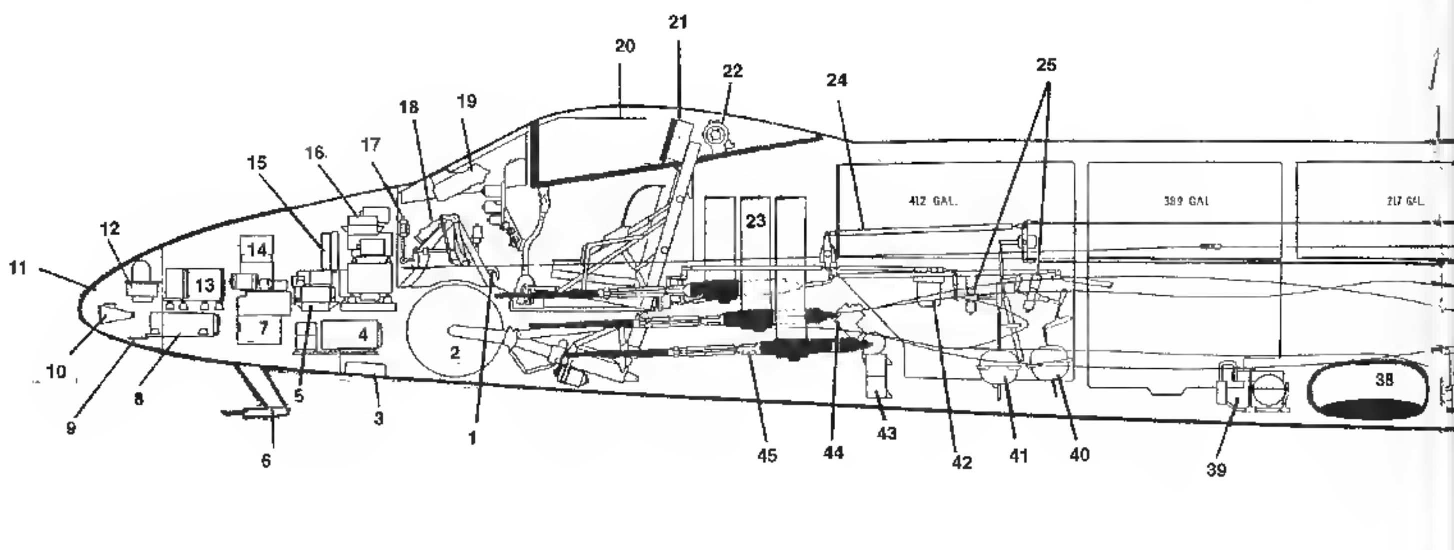




Above, the number two bird had the all-moving tail-plane installed. This is one of the few photos in which the range of adjustment that was available can be seen by the angle of degrees arc forward of the leading edge on the vertical tail. (Boeing, March 1954) At right, one of McDonnell's final offers to the Air Force was this 2-seat all-weather version in 1948. The cockpit would have been lengthened 3-feet. (Boeing)

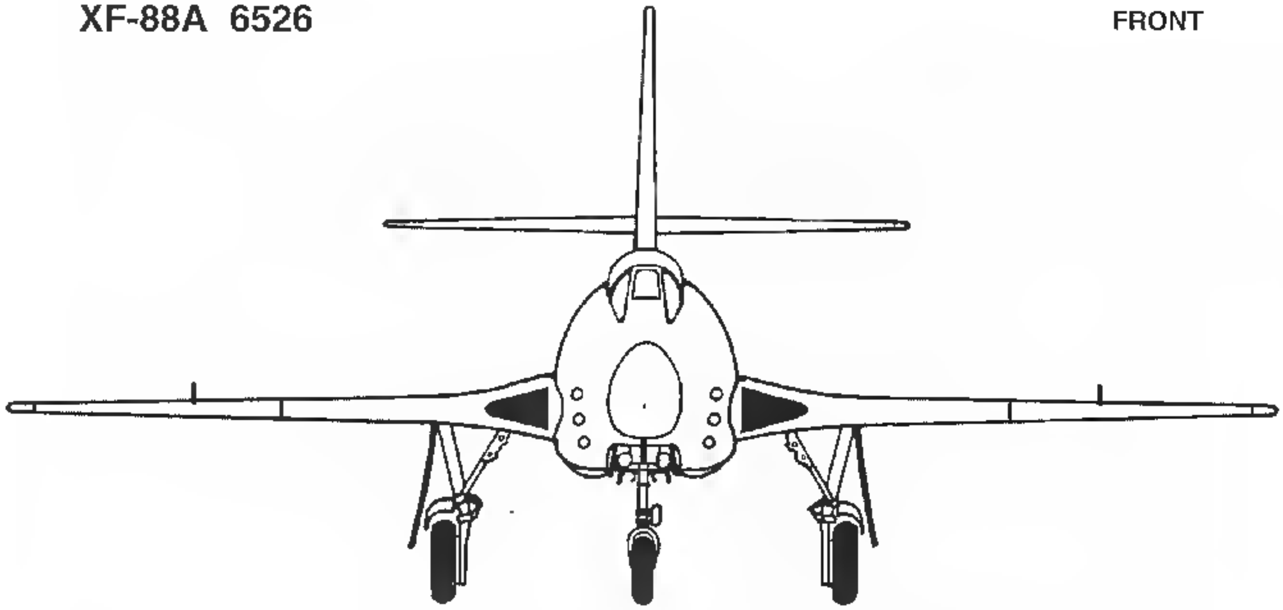
INBOARD PROFILE PROPOSED PRODUCTION F-88 WITH J48 ENGINES

1.) Parking Brake
2.) Nose Gear
3.) Marker Beacon Antenna
4.) ARC-3 Radio
5.) Amplifier
6.) Pitot Tube
7.) Batteries
8.) Radar Transmitter
9.) Glide Path Antenna
10.) Radar Antenna
11.) Radome
12.) Loop Antenna
13.) Radar Range Power Unit
14.) IFF Receiver
15.) Range Gear Box
16.) Computer
17.) Rudder Feel System
18.) Brake Cylinder
19.) Gun Sight
20.) Localizer Antenna
21.) Ejection Seat
22.) Cabin Air Regulator
23.) Ammunition Compartment
24.) Elevator Controls



XF-88A 6526

FRONT

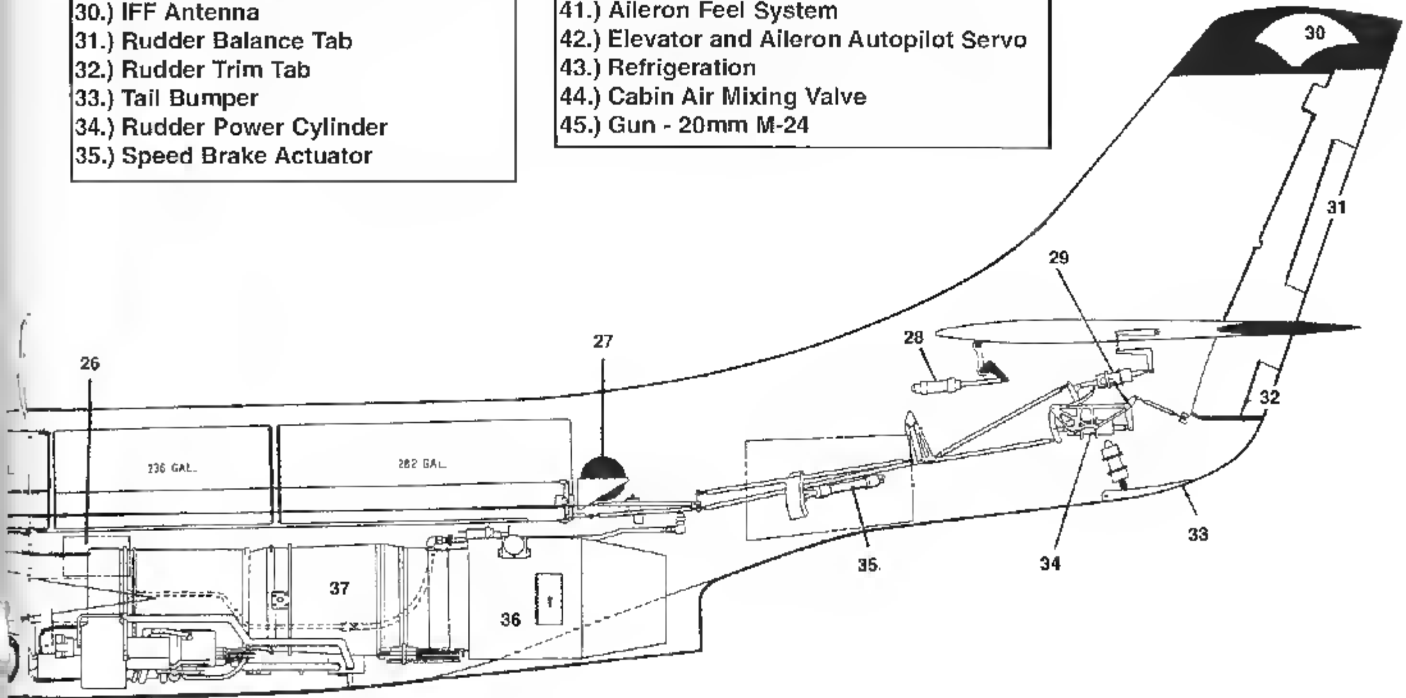


1/72 scale

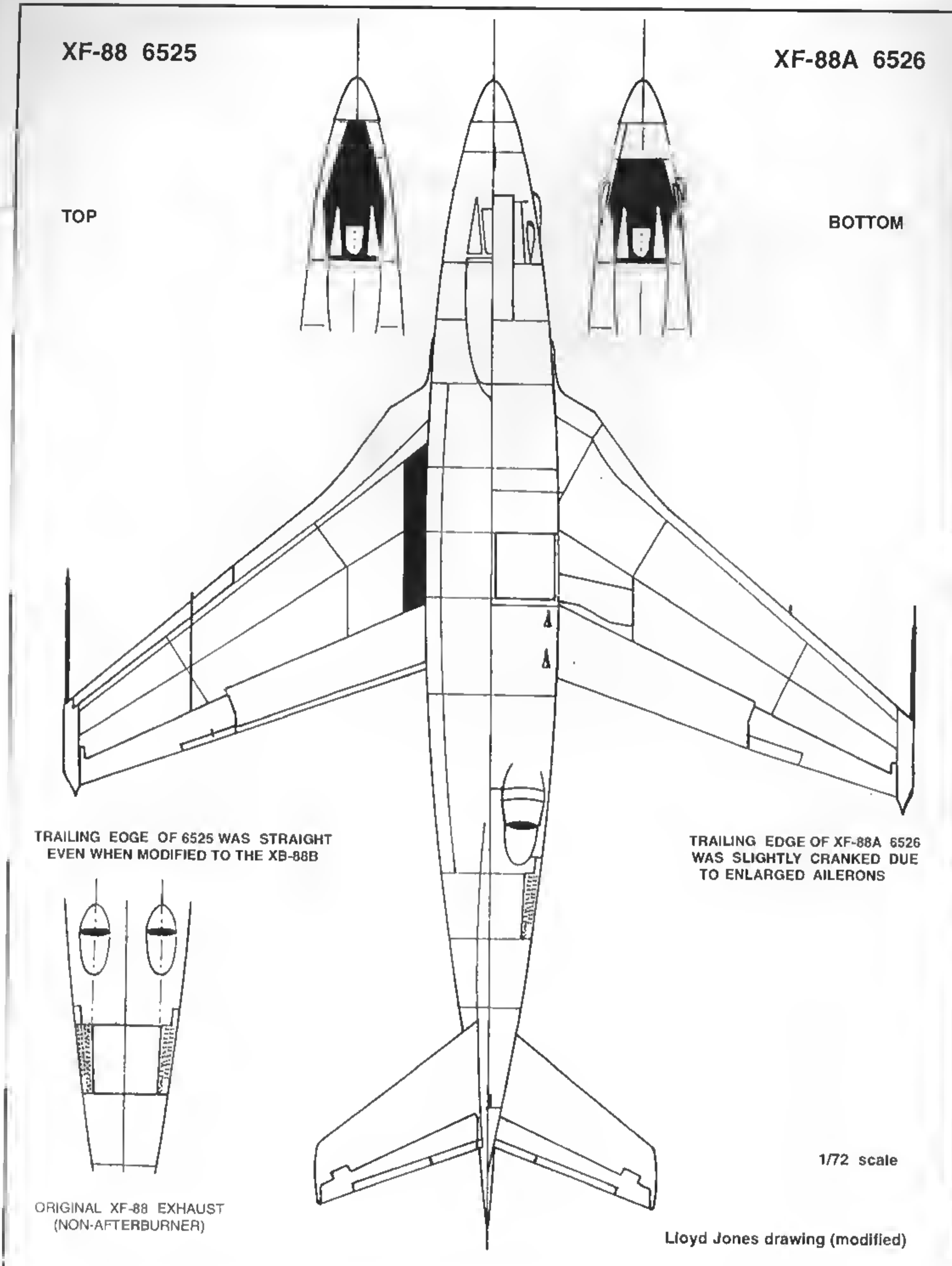
Lloyd Jones drawing

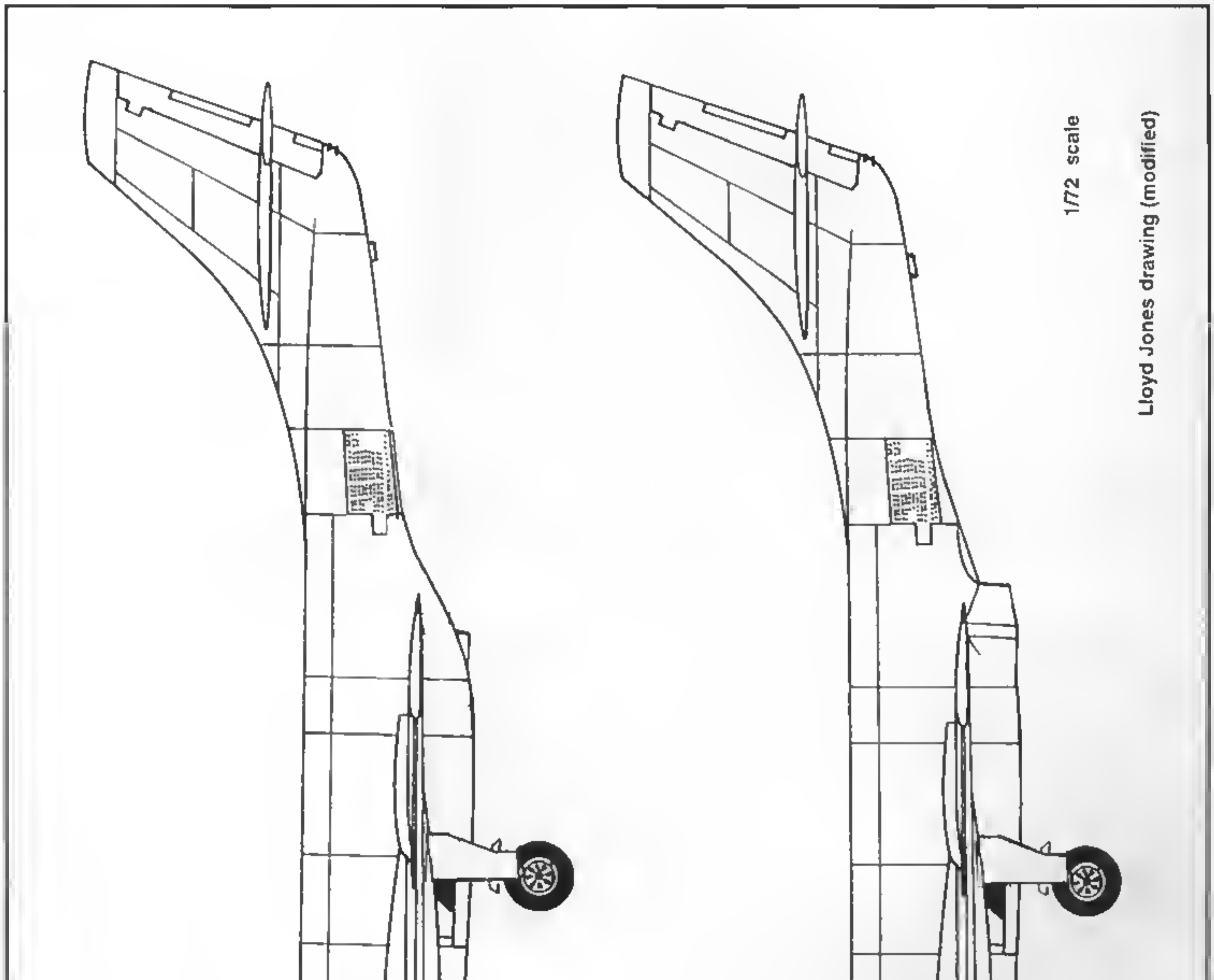
25.) Feel System Trim Actuators
26.) Hydraulic Reservoir
27.) Fire Extinguisher
28.) Adjustable Stabilizer Actuator
29.) Elevator Power Cylinder
30.) IFF Antenna
31.) Rudder Balance Tab
32.) Rudder Trim Tab
33.) Tail Bumper
34.) Rudder Power Cylinder
35.) Speed Brake Actuator

36.) Afterburner
37.) Westinghouse Engine J46-WE-2
38.) Speed Brake Actuator
39.) Hydraulic Compartment
40.) Elevator Feel System
41.) Aileron Feel System
42.) Elevator and Aileron Autopilot Servo
43.) Refrigeration
44.) Cabin Air Mixing Valve
45.) Gun - 20mm M-24



1/48 scale


XF-88 6525
XF-88A 6526
TOP
BOTTOM
TRAILING EDGE OF 6525 WAS STRAIGHT EVEN WHEN MODIFIED TO THE XB-88B
TRAILING EDGE OF XF-88A 6526 WAS SLIGHTLY CRANKED DUE TO ENLARGED AILERONS
ORIGINAL XF-88 EXHAUST (NON-AFTERBURNER)
1/72 scale
Lloyd Jones drawing (modified)

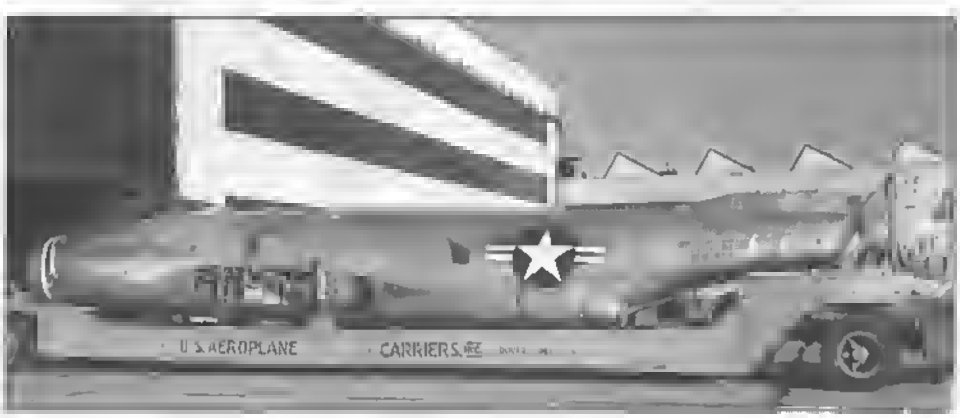

XF-88 6525 (NON-AFTERBURNER)
McDONNELL
XF-88
XF-88A 6526
1/72 scale
Lloyd Jones drawing (modified)

With a MAC Short afterburner unit installed on the left-hand engine only, and with a fixed exhaust nozzle on the right, the first in-flight afterburner operation with the XF-88A occurred on 9 June 1949. The test was a success and an afterburner unit was installed on the right-hand engine as well.

Meanwhile, negotiations had been underway for installation of a Model 501F-1 Allison 2,500 estimated shaft horsepower (eshp) XT38-A-5 turboprop engine in the nose of the number one Voodoo for a series of supersonic propeller demonstration flights. Thus, on 15 July 1949, McAir was awarded a contract to make the conversion, to create the XF-88B "tri-motor" (contract number AF-7442). For this conversion, the number one Voodoo was removed from flight duty after it had flown 90 times.

While in storage at St. Louis, awaiting its conversion into the XF-88B tri-motor configuration, MAC Short afterburner sections had been installed on its new J34-WE-15 turbojet engines, it too being given the XF-88A designation. In its new afterburner-equipped configuration, it made its first flight on 1 May 1950. It was ferried to Edwards AFB on 22 May.

Following its wheels-up crash landing on 9 November 1949 and subsequent repair, the XF-88A flew again at St. Louis on 27 March 1950 and was returned to Edwards AFB for preparation for the upcoming Penetration Fighter fly-off competition. But, on 16 June, USAF Maj. Frank K. "Pete" Everest, Jr. was forced to make a second wheels-up landing after hydraulic failure due to an engine compressor shutdown. Thus, to meet the fly-off commitment, Voodoo number one had to be substituted. It had been re-engined in May with afterburning J34s and re-designated XF-88A.



On 16 June 1950, just 13 days before the fly-off competition was to begin, 6526 made a wheels-up landing at Edwards. At left, trailer with wings and tail arrive at MacAir. Tailplane is removed. Second trailer with fuselage at MacAir. (McDonnell via Fred Roos)

Then, during 29 June and 7 July 1950, the fly-off competition between the McDonnell XF-88A Voodoo (46-525), Lockheed XF-90A "Super Star" and North American YF-93A "Sabre Cat" was held. The three airframe contractors waited for the USAF's decision.

THE XF-88's COMPETITION

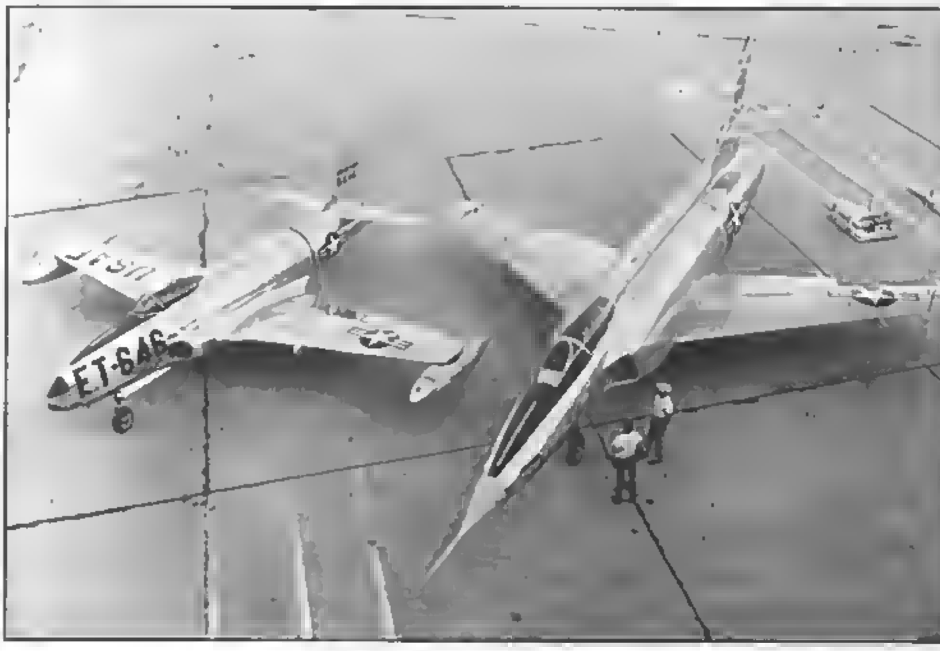
The XF-88's competition - the Lockheed XF-90/-90A and North American YF-93A - had all the problems suffered by the XF-88/-88A; namely, ever-changing mission requirements, inadequate propulsive systems and the day-to-day fighting between the military establishment and the politicians. In part, their histories are now discussed.

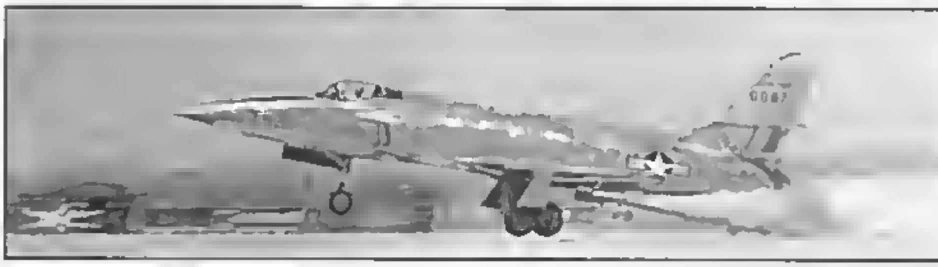
The Lockheed XF-90/-90A "Super Star"

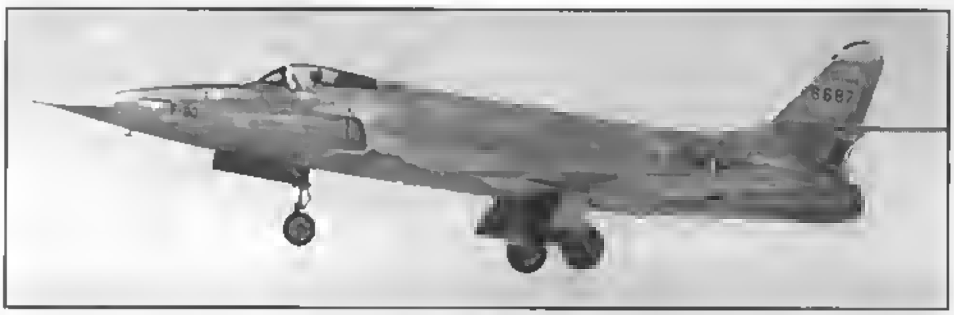
Unofficially named "Super Star," the Lockheed XF-90 and XF-90A Penetration Fighter contenders were literally ahead of their time.

During preliminary design, Lockheed investigated at least 65 configurations for its proposed Penetration Fighter airplane. Among these were swept back winged versions with butterfly or Vee tails, versions with W-shaped wings, versions with three turbojet engines (one on either wingtip and one in the fuselage) and delta-winged versions. Finally, Lockheed submitted its Temporary Design Number (TDN) L-153 to the Air Materiel Command.

Lockheed's TDN L-153 design featured a long, sleek fuselage with a







At right, F-90 poses with P/F-80 (AFFTC/HO) Prior to installation of afterburners, jet assisted take off was the only way to get the underpowered F-90 off the ground. (via Fred Freeman) The landing gear was not raised during the first (unofficial) flight on 3 June 1949. (AFFTC/HO) Tip tanks added 667 gallons to the F-90's fuel supply. (via Fred Freeman)

At left, total fuel capacity with tip tanks was 1,665 gallons (AFFTC/HO)

single-place cockpit and two tail-mounted Westinghouse J34 turbojet engines, fed air via cheek-type engine air inlets on either side of the fuselage. All of its flying surfaces were swept back, and both the vertical and horizontal tail planes had a variable-geometry feature whereby their sweep back and incidence (respectively) could be changed in flight. It was a most exotic design for the era and, in fact, for some years to come.

The AMC approved Lockheed's Penetration Fighter offering and ordered two XP-90 prototypes (S/Ns 46-687/-688), a full-scale engineering mockup, a static test article, wind tunnel models and engineering data on 20 June 1946 (Contract Number W33-038-AC-14563). Then, Lockheed's TDN L-153 became Model 090-32-01.

For some reasons that remain unclear, McDonnell's XF-88 design moved to hardware stage some ten months sooner than Lockheed's XF-90 design: the XF-88 mockup was ready for inspection first, XF-88 number one rolled out first and the airplane flew first. Nevertheless, Lockheed moved forward on the XF-90 project, and on 2-6 December 1947, the first XP-90 mockup conference was held.

And, as far as Lockheed's acquisition of an afterburner section went, on 5 December 1947, Westinghouse agreed to a joint Tailpipe Burner (TPB) program. In other words, while McAir was developing its own MAC Short afterburner, Lockheed and Westinghouse initiated a co-development afterburner program. As a matter of interest, the afterburning J34 engine slated for use on the XP-90 was initially tested on the number two XP-80A Shooting Star prototype.

By the time XF-90 number one was completed (15 March 1949) and trucked to Edwards AFB on 25 May 1949, both of McDonnell's XF-88s were flying. In fact, XF-88 number one had been flying for some seven months already.

After the usual ground tests and evaluations, including low-, medium- and high-speed taxi runs, XF-90 number one was cleared for flight. On the morning of 3 June 1949, Lockheed chief test pilot - the legendary Anthony W. "Tony" LeVier - rotated and flew XF-90 number one up and away from the dry lakebed. This was the unofficial first flight; duration was 30 minutes. The official first flight occurred the next day. As predicted though, and proved by XF-88 flights, its performance with non-afterburning J34 engines was less than spectacular. In fact, due to the XF-90's higher gross weight (31,060 lbs. compared to the XF-88's 18,500 lbs.), it had to rely on the use of Assisted Take-Off (ATO) units to even get off the ground on the first and subsequent flights. For even on the first flight takeoff, LeVier nearly ran out of room, just clearing the base's boundary fence. The four 1,000-lb. thrust ATO units - two on either side of the fuselage were indeed necessary.

Of the type's overall performance, the late Tony LeVier commented: "The XF-90's general performance was very poor. It wasn't a hell of a lot better with afterburner. The plane would have had a good chance for success had it had good engines, which it didn't. The aircraft was the only one in the competition that met military specifications in regard to

At left, both F-90s in flight together; Tony LeVier is in the foreground and Herman "Fish" Salmon is flying in the background. (Lockheed Martin)

structural strength, so it was much heavier than the other contenders were. The XF-90 was the third plane in the world to dive supersonic. The plane was also strong as hell; you couldn't over-stress it in flight."

As a matter of interest, between 1-20 May 1950, Levier made a series of 15 supersonic dive flights. On 17 May, a best of 1.12 Mn was achieved. These were attained in XF-90A number two, powered by two Westinghouse J34-WE-15 engines with afterburners. The first example was powered by two J34-WE-11 engines.

The number two XF-90 (46-688), powered by two afterburning J34-WE-15s, made its first flight in early May 1950. But on 11 May, after a hydraulics failure, it was forced to make a wheels-up belly landing, with little damage. The pilot forgot to extend the leading edge slats on 25 May, and XF-90 number one crashed from about 40 feet high and its tail cone was damaged. The airplane was quickly repaired and flew again the next day. This prompted the legendary Clarence L. "Kelly" Johnson , founder and president of Lockheed's Skunk Works, to write in his XF-90 log: "Airplane certainly is tough."

Seven USAF pilots took part in the 29 June and 7 July 1950 Penetration Fighter fly-off. These included Lt. Cols. Dunham, Blackeslee and Muhurin, Majs. Butcher and Rodewald, and Capts. Aust and Gibson. The nine-day event was essentially over before it started, as when it occurred, the Penetration Fighter program had already been terminated by the USAF.

As it came about, the Soviet Union detonated Joe I, its first atomic bomb, in Siberia in September 1949. That occurrence was verified several days later when scientists around the world measured its radioactive fallout. Now that Russia had the atomic bomb, and was building long-range bomber aircraft capable of delivering it, priorities changed within the USAF. Simply stated, the USAF now needed dedicated fighter-interceptor aircraft to defend North America from possible nuclear attack from long-ranging Russian bombers. In this fight, the fly-off between the XF-88A, XF-90A and YF-93A was mostly a formality.

In what must have been an unfair teaser to Lockheed, on 15 August 1951, nearly a year after the end of the Penetration Fighter program, the USAF asked Lockheed for price quotes on ten service test YF-90s and 222 production F-90s as ground attack airplanes. By the middle of September, with no further USAF input, Lockheed itself dissolved the F-90 project permanently.

The number two XF-90 was taken to Frenchman's Flat in Nevada to be destroyed during the parked aircraft phase of atomic Operation TUMBLER/SNAPPER held in April 1952. In September 1953, XF-90 number one was turned over to the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics (NACA now NASA).

XF-90/-90A Specifications

Wing span: 40 ft. (all versions)
Wing area: 345-sq. ft. (all versions)
Height: 15 ft. 9 in. (all versions)
Length: 56 ft. 2 in. (all versions)
Empty weight: 20,190 lb.
Gross weight: 28,000 lb.

Propulsion system: Two Westinghouse J34-WE-11 non-afterburning 3,000-lb. thrust turbojet engines; XF-90A used two J34-WE-15 afterburning 4,200-lb. turbojet engines

Armament: Six ventrally-mounted 20-mm cannons (207 rounds per gun) - the XF-90A (46-688) only; provision was made for either two 1,000-lb. bombs or eight 5-in. HVARs

Maximum speed: 667 mph in level flight (XF-90A); 1.12 Mn in a dive (XF-90A)

The North American YF-93A "Sabre Cat"

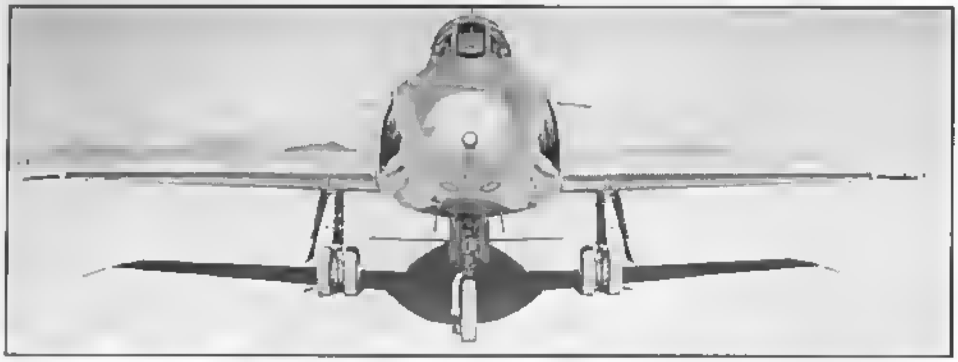
Nicknamed "Sabre Cat," the North American Aviation YF-93A was a latecomer in the Penetration Fighter competition.

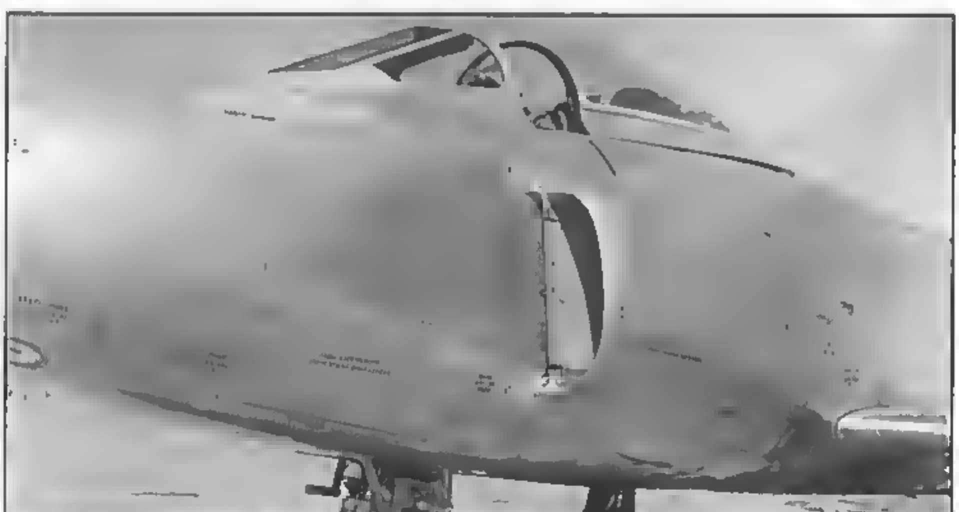
Although the specifications that were established by the Air Materiel Command on the Penetration Fighter program called for the use of two turbojet engines, North American Aviation (NAA) opted to design its proposal with just one: the upcoming Pratt & Whitney J48 centrifugal-flow turbojet engine (Model JT7) that it would produce under British license in the United States. Actually an Americanized Rolls-Royce R.Ta.1 Tay, the 6,000-lb. thrust P&W J48-PW-6 was to have an afterburner section to produce at least 8,000-lbs. thrust with afterburning. This was equal to the power output of two Westinghouse J34s installed in the XF-88 and XF-90 Penetration Fighter aircraft. What's more, one J48 weighed less than two J34s, and of course, used less fuel. However, centrifugal-flow turbojet engines have larger diameters than axial-flow turbojet engines. Thus, being based on its earlier F-86 Sabre Jet design, a fuselage redesign was required to accommodate the promising J48 engine, and was proceeded with.

NAA engineered fuselage side-mounted engine air inlets so that the nose of the aircraft would be free to house electronics and guns. In this way, the aircraft could be developed for the Penetration Fighter and All-Weather (Night) Interceptor roles at the sametime.

With its projected engine thrust rating of 8,000 lbs. with reheat, somewhat fighter weight, all-weather capability, six nose-mounted 20 mm cannon armament and advertised speed of 700 plus mph in level flight, NAA proposed its Model NA-157 or C version of the P-86 Sabre Jet to the newly established USAF on 20 September 1947. It was offered as either a Penetration Fighter or an All-Weather Interceptor. After a relatively short evaluation period, the USAF ordered 120 examples - two service test (S/Ns 48-317/-318) and 118 production aircraft - on 17 December 1947 (Contract Number W33-038-AC-21672). Since the type was quite different from the basic F-86 line, it was given a new designation. The two service test examples were designed YP-93A and the production aircraft were designated P-93A. (After 11 June 1948 these became YF-93A and F-93A.)

PENETRATION FIGHTER COMPETITOR, NORTH AMERICAN YF-93





The first of two YF-93A service test aircraft was completed, trucked to Edwards AFB in December 1949 and readied for flight. By this time, both XF-88s were flying as were both XF-90s. The YF-93A, therefore, had a lot to prove in a very short time.

North American Aviation chief test pilot George S. "Wheaties" Welch initially flight tested the first YF-93A on 25 January 1950. Subsequent test hops, especially where the aircraft was subjected to high angles of attack, showed that its flush engine air inlets starved the J48 engine causing compressor stalls and flame outs. In tact, on 6 June 1950, the J48 engine in YF-93A number one exploded, but luckily for George Welch, engine debris didn't damage the airframe enough for disaster and he was able to make a successful emergency dead stick landing.

Conventional cheek-type engine air inlets were incorporated on the second YF-93A and the problem was eliminated.

Nevertheless, after lhe Penetration Fighter fly-ott, NAA's YF-93A came in last. The result: the production order for 118 F-93A aircratt was cancelled. Further, the order for one Model NA-166 All-Weather (Night) Fighter version of the F-93A was also cancelled.

NASA (then NACA) obtained both YF-93A aircraft in early 1951 for its ongoing series of flight test evaluations. It tlew the aircraft for several years before returning them to the USAF for tinal disposition. What became of them remains unclear.

At left top, YF-93A with original flush engine inlets. Note dual wheel main gear. Upper middle, first attempt to improve airflow to the starving engine was these enlarged flush style inlets. Above, cheek type intakes were the final solution to insufficient engine airflow. At left, close up of the cheek type intakes on 9-15-50. (NAA)

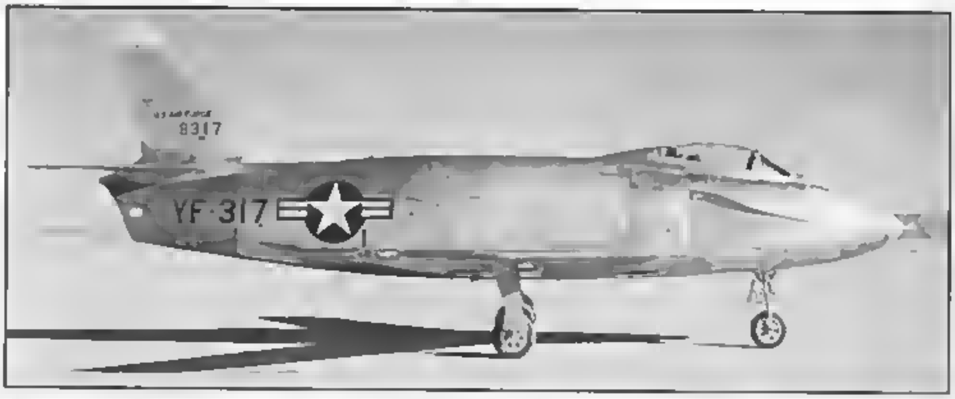
YF-93A Specifications

Wing span: 38 ft. 11 in. (both)
Wing area: 306-sq. ft. (both)
Height: 15 ft. 8 in. (both)
Length: 44 ft. 1 in. (both)
Empty weight: 14,035 lb.
Gross weight: 21,610 lb.
Propulsion system: One Pratt & Whitney J48-P-6 afterburning 8,750-lb. thrust turbojet engine

Armament: Six nose-mounted 20-mm cannons (200 rounds per gun); provision was made for either two 1,000-lb. bombs or eight 5-in. HVARs

Maximum speed: 708 mph in level flight; 1.05 Mn in a dive

At right, two views of the YF-93A prior to its first flight. Its F-86 lineage can be readily seen. (NAA) Below, YF-93A in flight with cheek style engine intakes. The YF-93A at 708mph was 67mph faster than the XF-88A and 40mph faster than the XF-90A while in level flight (Boeing) Bottom, both YF-93As were transferred to NACA in 1951. (via Fred Freeman)



Above, the number two ship makes a high speed pass at Smartt Field in July 1953. Below, on final in July 1953. Note the underbelly mast had been removed and the pitot tube was moved to the wing tip. (McDonnell via Fred Roos)

At right top, the second XF-88 Voodoo supported the F-101 test program and was fitted with a F-101 nose mockup for retueling gear testing. (McDonnell via Fred Roos) At right bottom, F-101A 53-2418 undergoing gear retraction tests in August 1954 with the second XF-88 in the background. First flight was on 29 September 1954 (Boeing)

POST FLY-OFF DEVELOPMENTS

As previously mentioned, the XF-88A (46-526) had been damaged during a wheels up emergency landing on 16 June 1950. Thus, fitted with MAC Short afterburners, the XF-88 (46-525) was also designated XF-88A for its substituted participation in the fly-off. At this time then, the Voodoo aircraft became known as XF-88A number one and XF-88A number two. In its damaged state, XF-88A number two arrived back at St. Louis on a truck on 11 July 1950, followed by XF-88A number one on 3 August, which flew home.

Following the fly-off, the evaluation board's appraisal on 15 August 1950 gave first place to the XF-88A Voodoo, but noted that none of the three types possessed sufficient range and endurance to perform the Penetration Fighter mission. A letter from USAF AMC on 11 September 1950 notified McAir that its XF-88A Voodoo had been ranked number one of the three Penetration Fighter contestants, adding, "No procurement...is contemplated at this time." For all intents and purposes, the program had already been canceled - even though the USAF had recently requested that production F-88s (McAir Model 36F) be built. It was nice to know of their win, but without an F-88 production contract forthcoming, the announcement held little value.

Meanwhile, McAir had placed both of its XF-88As in storage; the number one airplane would still become the XF-88B (Model 36J). Believing their XF-88 was a sound design, McAir kept designing derivatives of it. This effort ultimately payed off in the subsequent Model 36W program, which spawned the F-101A Voodoo under Weapon System (WS) 105A.

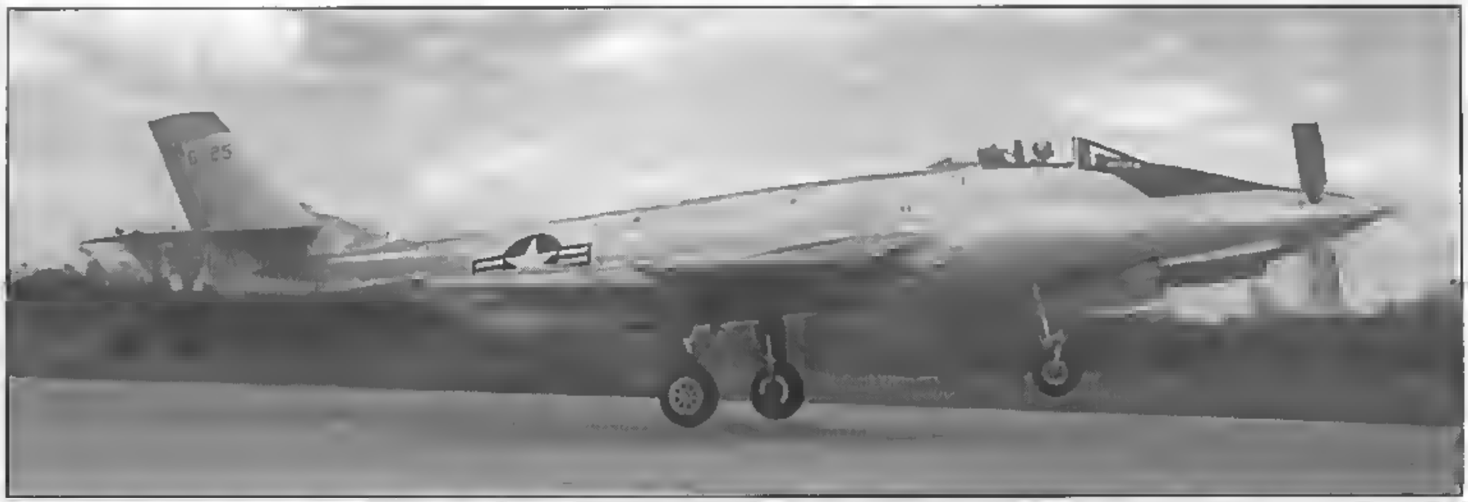
The original XF-88A, now known as XF-88A-2, was repaired and continued to fly in support of F-101 development and in-flight refueling tests. In the meantime, XF-88A number one had been undergoing modification to become the XF-88B supersonic propeller test bed.


U.S AIR FORCE

NACA XF-88B SUPERSONIC PROPELLER TEST BED

Now designated XF-88B, the number one Voodoo made its first flight as such at Lambert Field on 14 March 1953. Testing for NACA (NASA after 1958) lasted until 1957, during which time a number of supersonic propeller variants had been mounted to the Allison turboprop engine. The highest speed attained was 1.12 Mn in a power dive - one of the fastest speeds ever recorded for a propeller-driven airplane - as its two turbojet engines had been shut down for that particular test flight.

While it was at NACA's (now NASA) Langley Research Center, it made 43 research flights. The last of these flights was in January 1958.



At left top, MacAir family photo with FH-1 Phantom, F2H-4 Banshee, XF-88B, and XF3H-1 Demon. (McDonnell via Fred Roos) Middle, Allison XT38-A-5 turboprop engine is fired up for engine test in early 1953. (via Robert F. Dorr) Bottom left, rollout publicity shot of the XF-88B after the modification program was completed. (via Rick Koehnen)

Above, XF-88B breaks ground at MacAir in 1953 during initial testing. (McDonnell via Rick Koehnen) Below, gear retraction after lift-off. Note the off-center nose gear which had been moved from the centerline to the right side of the fuselage. (McDonnell via Fred Roos) Bottom, right side view over the St. Louis countryside. The right side turboprop inlet was located almost a foot closer to the prop than the left one. (McDonnell)

At left top, XF-88B In flight over Saint Louis on 11 July 1953. The oval shape on the lower fuselage opposite the wing intakes was the turboprop's exhaust. (McDonnell via Fred Roos) At left, XF-88B takes off from the McDonnell plant. The nose gear retracted prior to the main gear. (McDonnell) At left bottom, the XF-88B undergoes maintenance after assignment to NACA Langley. Note that a 3-blade prop had replaced the original 4-blade unit. (NASA via Robert F Dorr)

Above and below, XF-88B with supersonic propeller type Va spherical spinner Installed over the short-blade prop. A pressure rake was Installed on both sides of the fuselage for monitoring the prop's air turbulence. The head-on view below offers a good view of the offset nose gear. Bottom, XF-88B with the NACA emblem painted on a yellow tail stripe. The original pointy-nose has been re-Installed with long-style 3-blade prop. (NACA via Rick Koehnen)

THE PROPOSED F-88 VOODOO

McDonnell's proposed production Voodoo, the F-88, was never produced. In October 1947, McAir presented its F-88 proposal to the Air Force. On 15 March 1948, the AMC authorized McAir to proceed. Thereafter, a series of events and decisions were to determine the future of this aircraft.

Some two months later, on 13 May 1948, President Harry S Truman imposed a budget ceiling on fiscal 1950 funds (announced publicly the following January), and in December 1948, Gen. Joseph T. McNarney, commander of the AMC and also Chairman of the Defense Department Budget Advisory Committee, asked AMC directors to revise their 1949 and 1950 programs: first, to meet the reduced budget ceiling; and last, to pack more atomic firepower into Strategic Air Command's bomber squadrons. This meant that most of the fiscal 1950 budget would be going into B-36 bombers, which the F-88 had not been designed to escort.

On 16 December 1948, the Engineering Division, AMC, asked McAir to stop design and development work on its F-88. However, McAir continued to revise F-88 engineering paperwork for presentation to various fighter-evaluation boards.

The proposed production F-88 Voodoo (Model 36F) was to be powered by two afterburning Westinghouse Model 24C-10 or -10D engines. Respectively designated as J46-WE-4 and J46-WE-8, these engines were some four feet longer and somewhat bigger around than their J34 counterparts. In other words, the proposed production version of the F-88 Voodoo was longer (by some four feet) and had a deeper fuselage. And, of course, the airplane would have needed larger internal fuel tanks. Both versions of the J46 turbojet engines produced about 4,500 pounds thrust without afterburning and some 6,000 lbs with. Other engines were also considered: the Allison J71, General Electric J47 and Pratt & Whitney J57 among others.

McDonnell proposed other versions of the XF-88, including a two-seat All-Weather (Night) Fighter in 1948. It would have been some three feet longer than the XF-88 aircraft, but was abandoned in favor of procuring North American's F-86D "Sabre Dog" (WS-206A), Northrop's F-89J Scorpion (WS-205G) and Lockheed's F-94C Starfire aircraft.

XF-88/XF-88A/XF-88B Specifications

Wing span: 39.8 ft. (all versions)

Wing area: 350-sq. ft. (all versions)

Height: 17.3 ft. (all versions)

Length: 54.2 ft. (XF-88 and XF-88A; 58 ft., 5.5 in. for XF-88B)

Empty weight: 12,140-lb. (XF-88B 14,500-lb)

Below, the number two ship ended up at Langley as a parts bird for the XF-88B. It is seen here in the dump at Langley in 1958. (by Robert F Dorr)

XF-88B NOSE MODIFICATION

Gross weight: 18,500-lb. (22,000-lb. for XF-88B)

Propulsion system: Two Westinghouse J34-WE-13 non-afterburning 3,200-lb. thrust turbojet engines, or two J34-WE-15 afterburning 4,200-lb. thrust turbojet engines; XF-88B used two J34-WE-15 afterburning engines and one Allison XT38-A-5 2,650 eshp turboprop engine

Armament: Six nose-mounted M-24 20-mm cannons with 220 rounds of ammunition each - the original XF-88A (46-526) only; provision was made for either two 1,000-lb. bombs or eight 5-in. HVARs

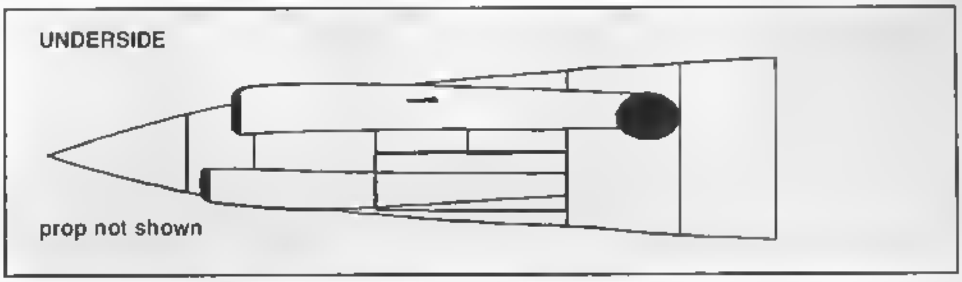
Maximum speed: 641 mph in level flight (XF-88A); 1.175 Mn in a dive (XF-88); 1.12 Mn in a dive (XF-88B)

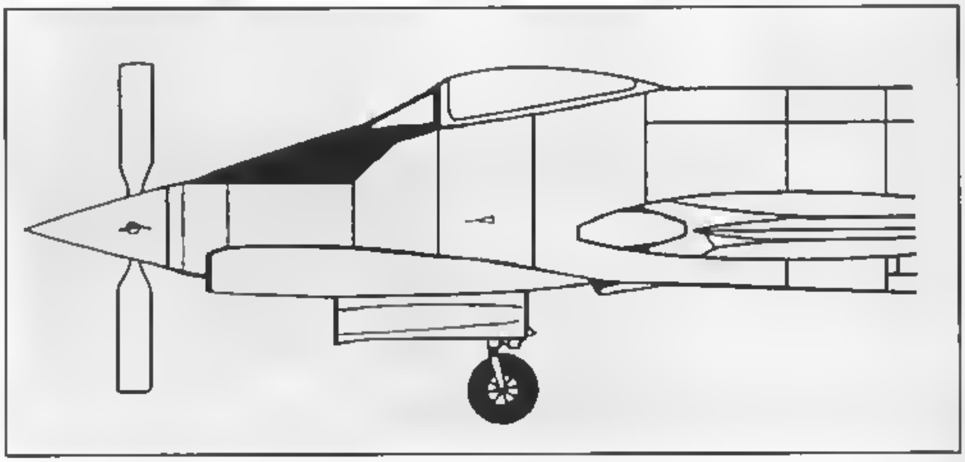
CONCLUSION

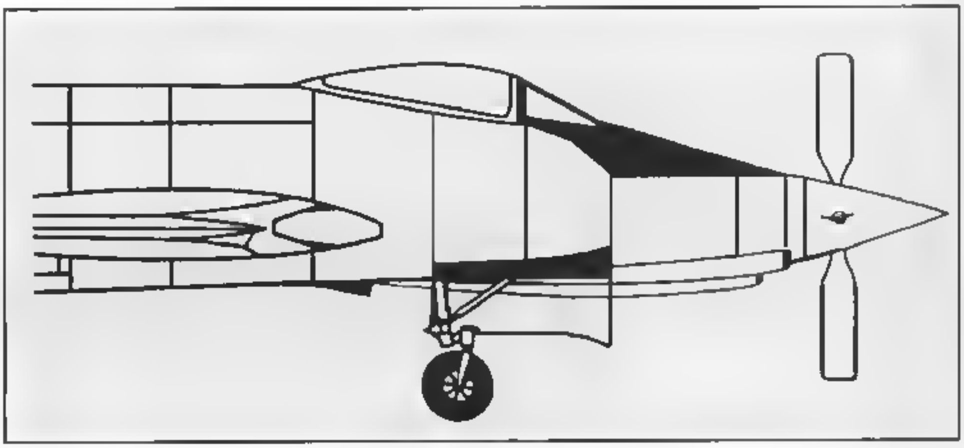
Neither the XF-88 (46-525) nor the XF-88A (46-526) Voodoo aircraft survived, as they were both scrapped-out in the early 1960s (the former being the XF-88B at the time). But because of their respective successes, in May 1951 the McAir Model 36W - the F-101A Voodoo was declared the winner of the USAF's long-range fighter competition.

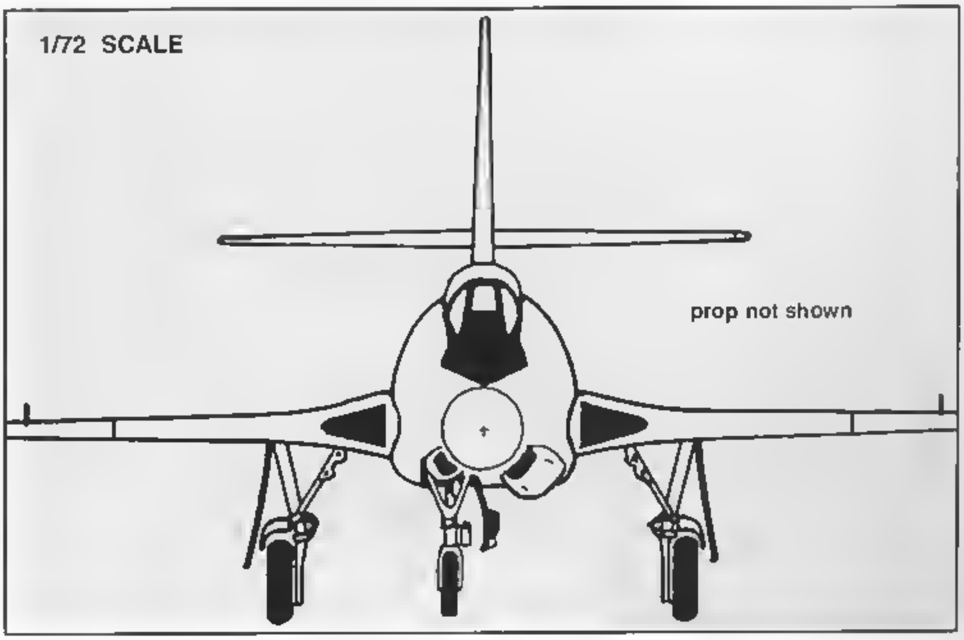
Winning an F-101A production contract in early 1952, McAir went on to produce more than 800 Voodoo fighters in a number of production versions including: the F-101A (36W), RF-101A (36Y), F-101B (36BA), CF-101B, TF-101B, F-101C (36CM), RF-101C (36CA) and TF-101F.

Without the advent of the XF-88, XF-88A and XF-88B Voodoo series of aircraft, and the lessons learned through their design, development, manufacture and flight test activities, McDonnell Aircraft would not have earned the right to build the "One 'O Wonder," its very first USAF production aircraft.

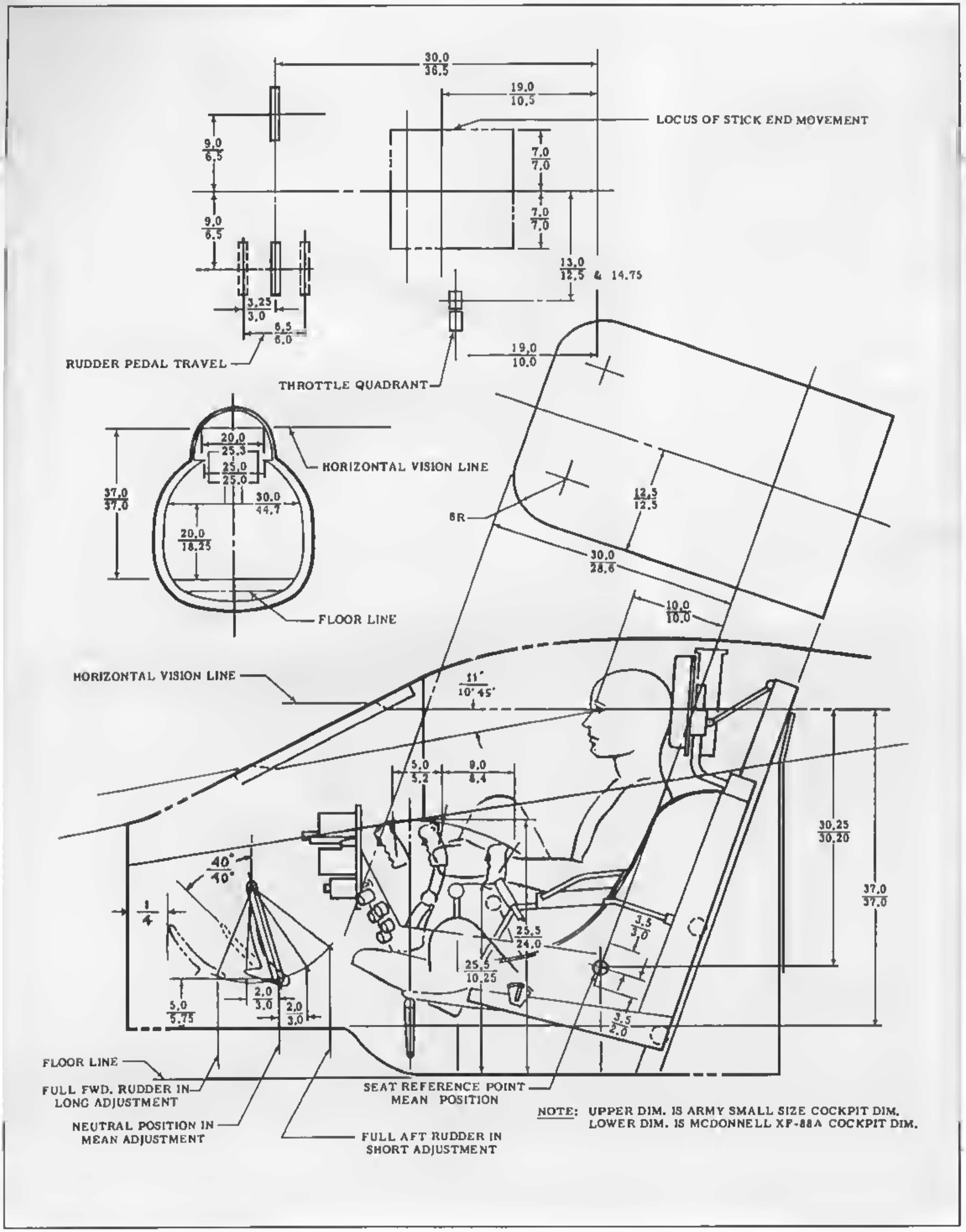


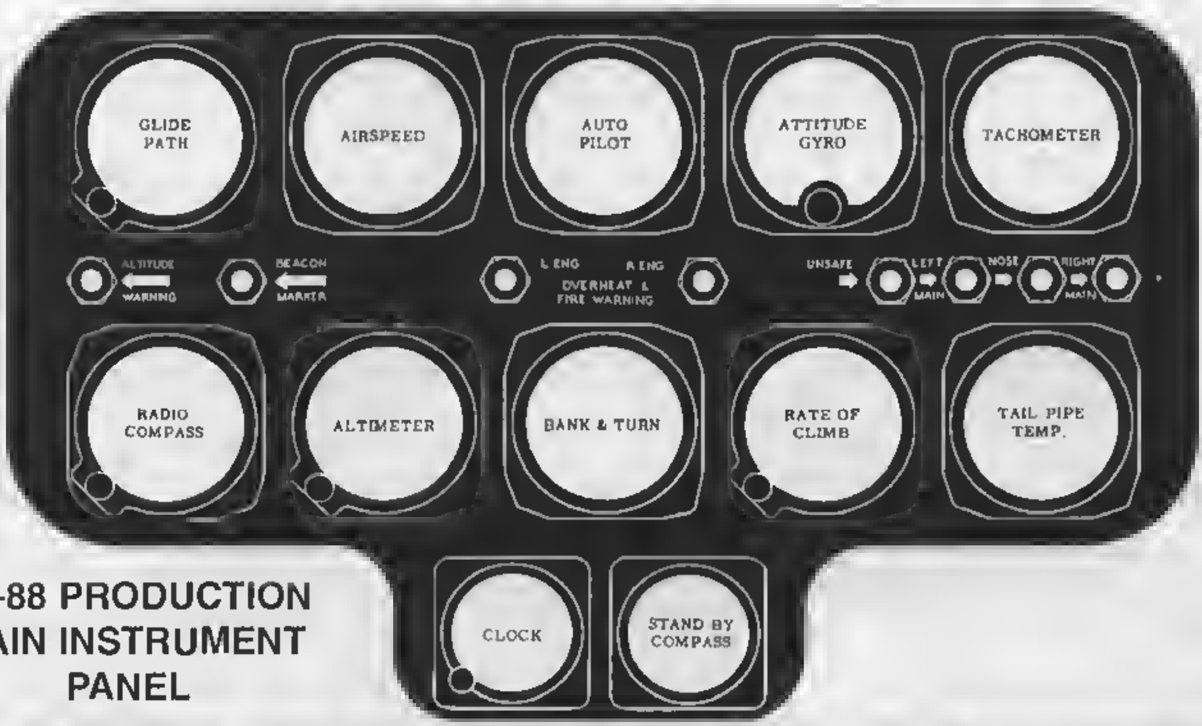




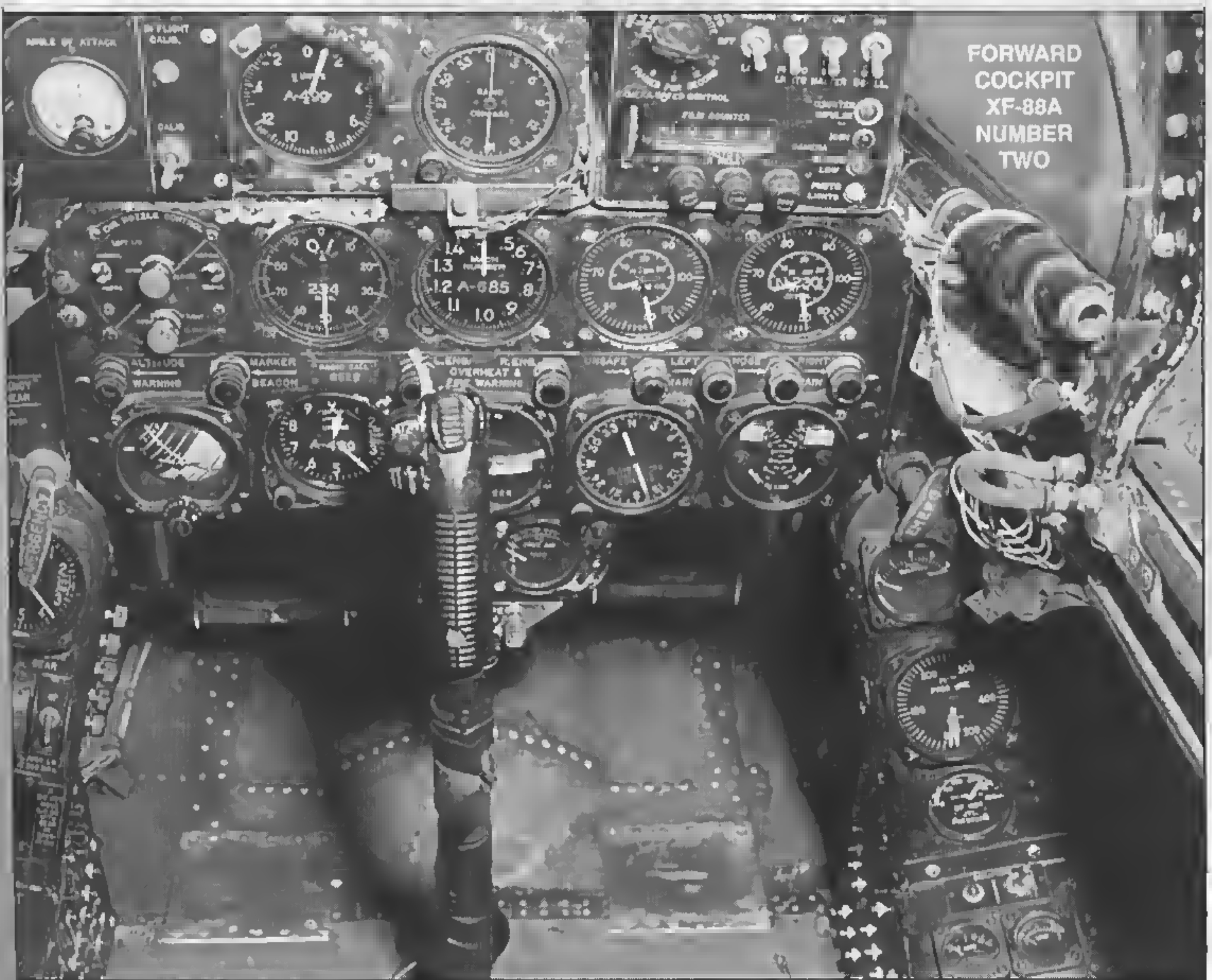


XF-88 COCKPIT ARRANGEMENT



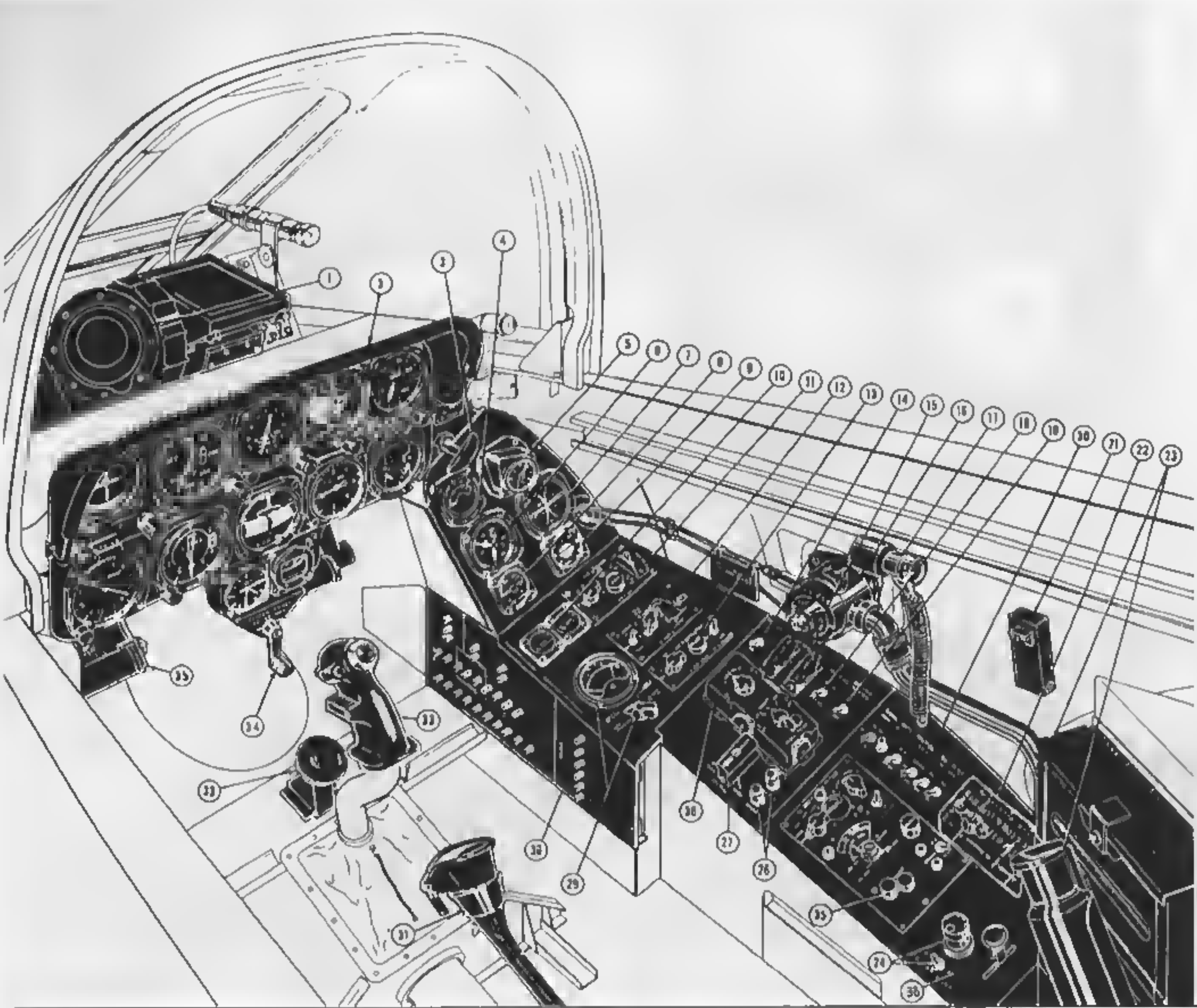


XF-88 PRODUCTION MAIN INSTRUMENT PANEL



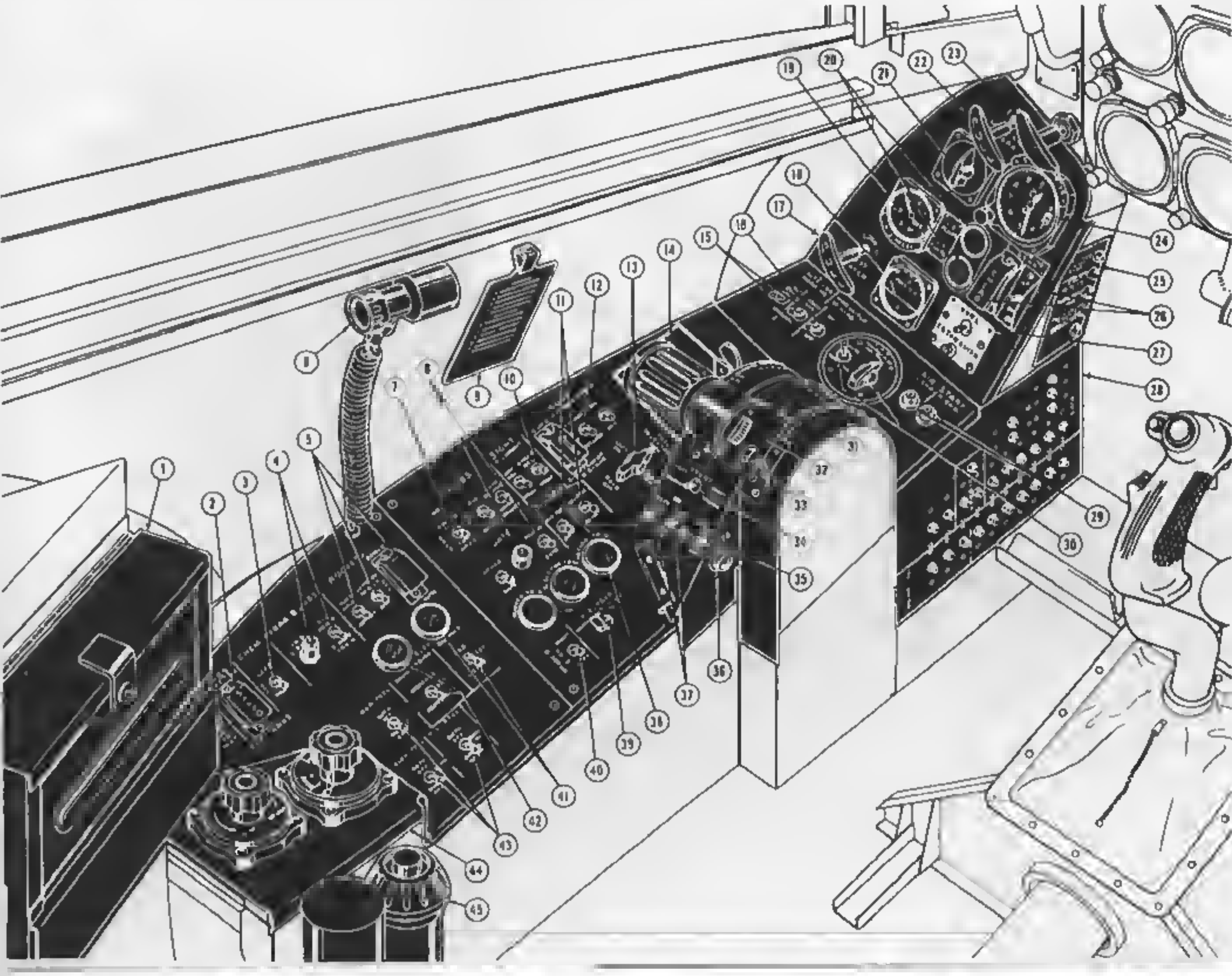
FORWARD COCKPIT XF-88A NUMBER TWO

XF-88 PILOT'S RIGHT - HAND CONSOLE



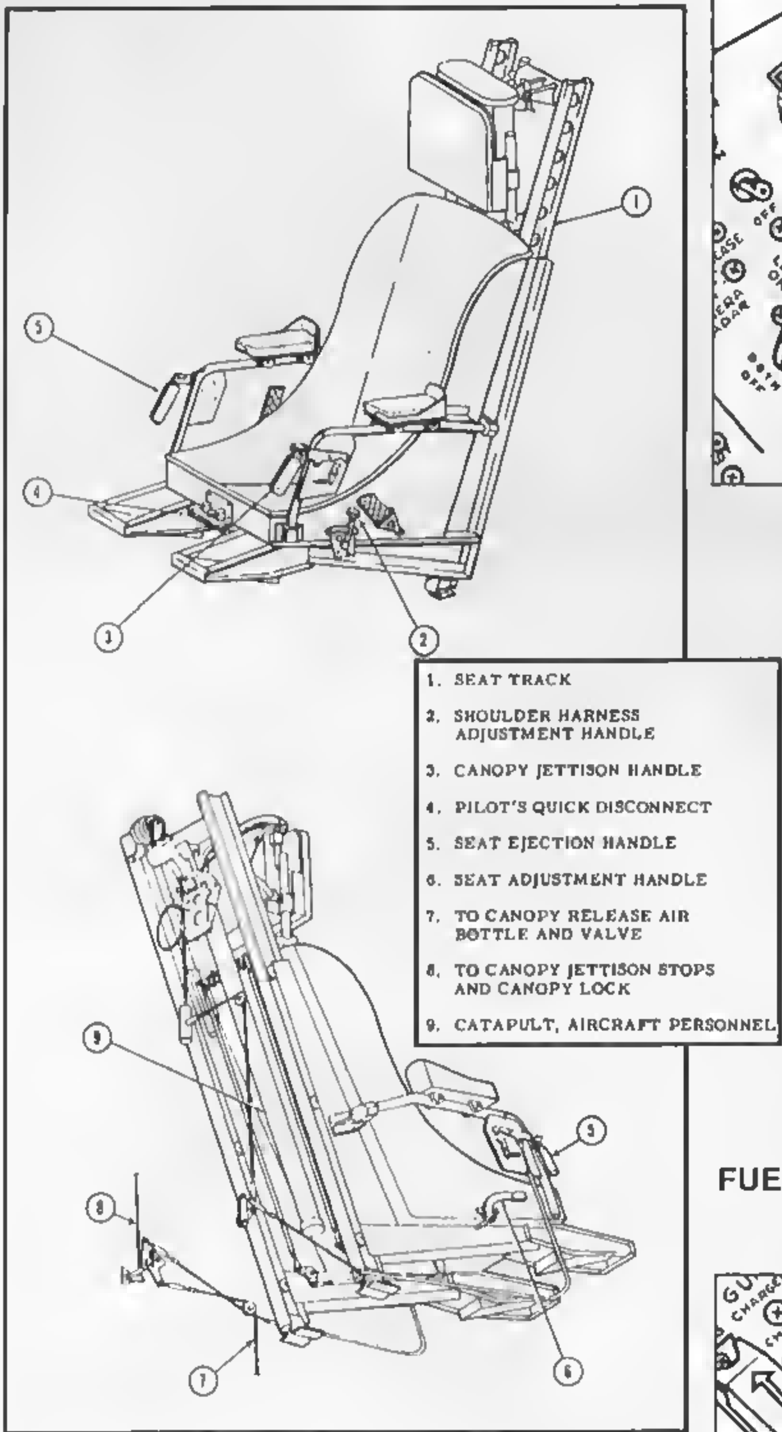
1. GUN, BOMB, AND ROCKET SIGHT
2. MAIN INSTRUMENT PANEL
3. EMERGENCY FLAP RELEASE
4. FUEL QUANTITY GAGE
5. ACCELEROMETER
6. FUEL PRESSURE GAGE
7. OIL PRESSURE GAGE
8. OXYGEN PRESSURE GAGE
9. OXYGEN FLOW METER
10. AMMETERS
11. AN/ARC-3 VHF RECEIVER-TRANSMITTER
12. SCR-695-B IFF RADIO RECEIVER
13. GROUND CONTROLLED APPROACH EQUIPMENT - RC103A AN/ARN-5
14. BATTERY SWITCH
15. GENERATOR SWITCHES
16. OXYGEN REGULATOR
17. COCKPIT LIGHT
18. INVERTER SWITCH
19. HYDRAULIC POWER CYLINDER HEATER
20. EXTERIOR LIGHTING PANEL
21. SPARE FUSE BOX
22. GENERATOR VOLTAGE CONTROLS
23. MAP CASE AND THERMOS BOTTLE
24. COCKPIT LIGHT CONTROLS
25. RADIO COMPASS - AN/ARN-6
26. INVERTER FAILURE INDICATING LIGHTS
27. NORMAL CANOPY CONTROL
28. C-2 AUTOMATIC PILOT - FLIGHT CONTROLLEF
29. VOLTMETER SELECTOR SWITCH AND INDICATC
30. CIRCUIT BREAKER PANEL
31. RELIEF TUBE
32. CONTHOL STICK
33. PARKING BRAKE
34. RUDDER PEDAL ADJUSTMENT CRANK
35. RUDDER PEDAL
36. EMERG. VENTILATING SHUTOFF

XF-88 PILOT'S LEFT - HAND CONSOLE

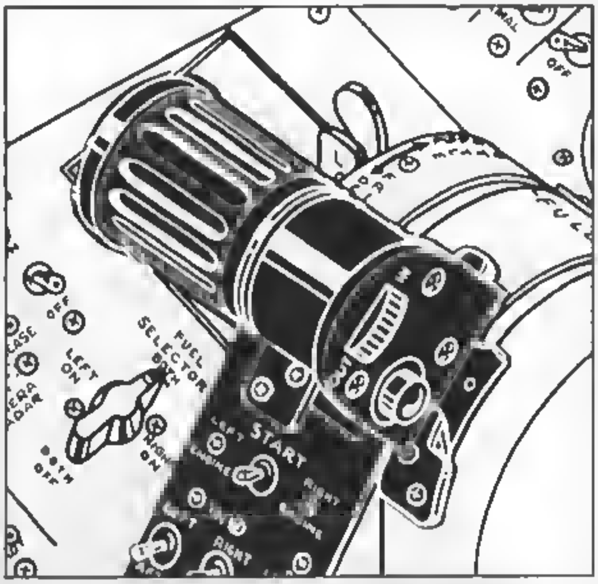


1. MAP CASE AND FLIGHT REPORT HOLDER
2. BOMBS, ROCKETS & TIP TANKS SALVO SWITCH
3. CHEMICAL TANK RELEASE CONTROL
4. FRAGMENTATION BOMB CONTROLS
5. ROCKET CONTRDLS
6. COCKPIT LIGHT
7. BOMB CONTROL PANEL
8. JATO CONTROLS
9. PILOT'S CHECK LIST HOLDER
10. GUN SIGHT CONTROLS
11. TIP TANK RELEASE CONTROLS
12. GUN CONTROL PANEL
13. FUEL SELECTOR VALVE
14. THRDTTLE CONTROLS
15. ALTITUDE AND LANDING WARNING CONTROLS
16. WINDSHIELD DE-ICING CDNTRDL
17. FOOT HEATER CONTROL
18. FREE AIR TEMPERATURE GAGE
19. HYDRAULIC PRESSURE GAGE
20. LEADING AND TRAILING EDGE FLAP INDICATORS
21. GUN SIGHT DRIFT CONTROLLER
22. EMERGENCY VENT CONTROL
23. EMERGENCY LANDING GEAR RELEASE
24. CABIN ALTIMETER
25. FUSE PANEL
26. NORMAL AND EMERGENCY LANDING GEAR CONTROLS
27. FIRE EXTINGUISHER
28. CIRCUIT BREAKER PANEL
29. AIR START CONTROLS
30. CABIN TEMPERATURE CONTROL
31. NOSE GEAR STEERING SWITCH
32. SPEED BREAK SWITCH
33. CAGING BUTTON - GUN SIGHT GYRO
34. STARTER SWITCH
35. LANDING LIGHT CONTROL
36. JATO
37. AFTERBURNER SWITCH
38. TRIM TAB INDICATORS
39. TRAILING EDGE FLAP CONTROL
40. RUDDER TRIM TAB CONTROL
41. ELEVATOR BALANCE TAB CONTROL & INDICATOR
42. ELEVATOR DOWN SPRING CONTROL & INDICATOR
43. FUEL SYSTEM CONTROLS
44. GUN BOMB, ROCKET SIGHT CONTROL PANEL
45. ANTI-BLACKOUT CONTROL

EJECTION SEAT AND CONTROLS

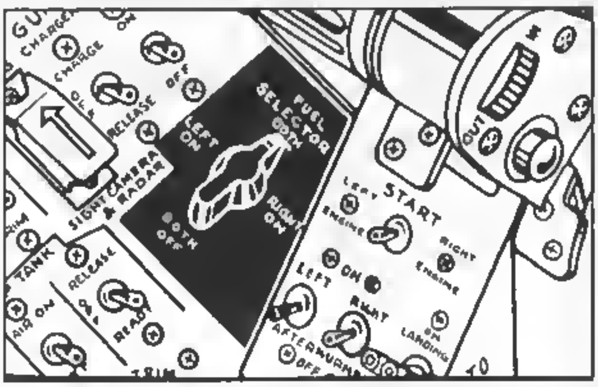


ENGINE CONTROLS

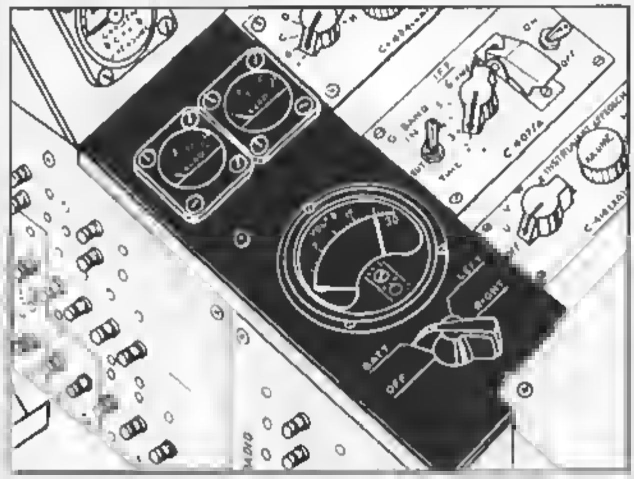


The engine controls required to operate the two turbo-jet engines were designed for simplicity and ease of operation. Controls were combined wherever possible or located together in the cockpit for ready accessibility to the pilot. The engine governor levers, starter, afterburner, and JATO switches were located on the power quadrant.

FUEL AND GUN CONTROLS



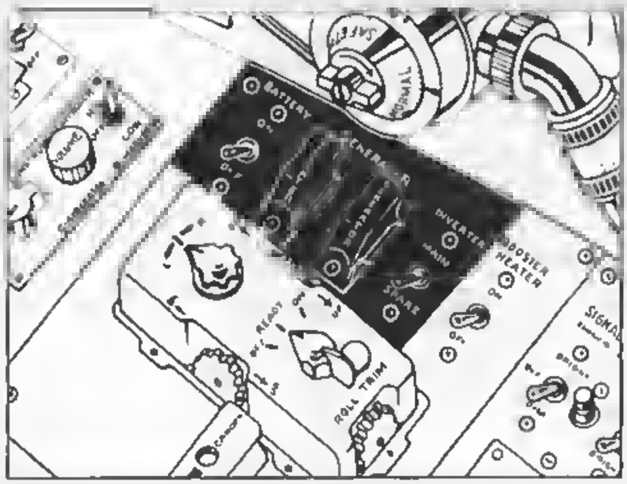
PRIMARY ELECTRIC CONTROLS



The primary electrical controls were comprised of two groups. These were the switchboard type and basic electrical type.

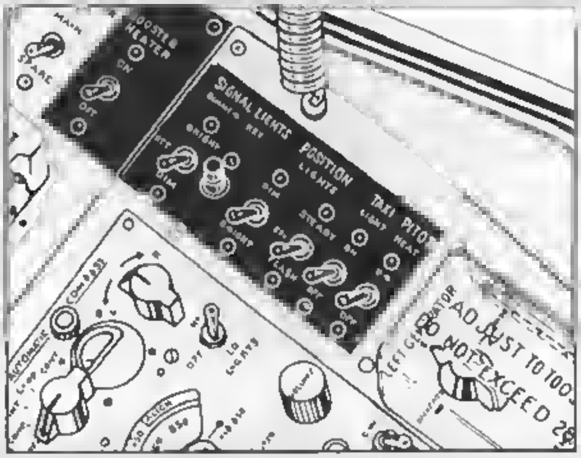
The switchboard type (above) were the voltmeter and selector switch, voltage regulators and ammeters. The ammeters were located on the right-hand forward console just aft of the instrument panel and console transition. The voltmeter and selector switches were in line just aft of the ammeters.

The basic electrical control group (below) of the primary electrical controls were the battery, generator and inverter switches, and the inverter lights. The battery, generator and inverter switches were located on the right center console, outboard of the autopilot controller.



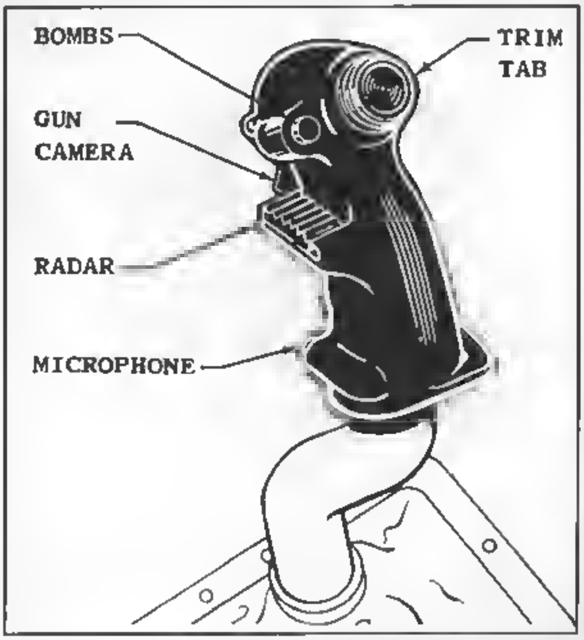
SECONDARY ELECTRICAL CONTROLS

The secondary electrical controls may be defined as the lighting, signaling, and miscellaneous electrical controls. These consist of the signal and position light controls, booster heater, pitot heater, taxi and landing lights, and instrument and cockpit light control assemblies.



PILOT'S STICK GRIP

The stick grip is of the B-8 type, incorporating an aileron and elevator trim control switch, radar in and out switch, gun and bomb switches and the microphone switch.



LINDBERG LINE 1/48 SCALE PLASTIC XF-88 VOODOO MODEL

Mc DONNELL

VOO DOO

KIT NO. 543

This new type of stand developed by Lindberg Products Inc. engineers, uses an aluminum wire that will bend to the position desired

Press and shape decals lightly over curved parts. When applying rudder decal, let dry and cut rudder loose with tip of knife or razor blade

Use enamel or plastic paints only. Do not use lacquer paint materials as these craze the plastic.
Paint the following: pilot *brown*, jet seat *gray*, tail section *yellow*, tires *black*, nose and spear *red*, wing tank tips *red*.

the LINDBERG line FAMOUS THE WORLD OVER

HISTORY OF THE McDONNELL "VOO DOO"

The McDonnell F-88 "Voo Doo" was designed to meet specifications of the U.S

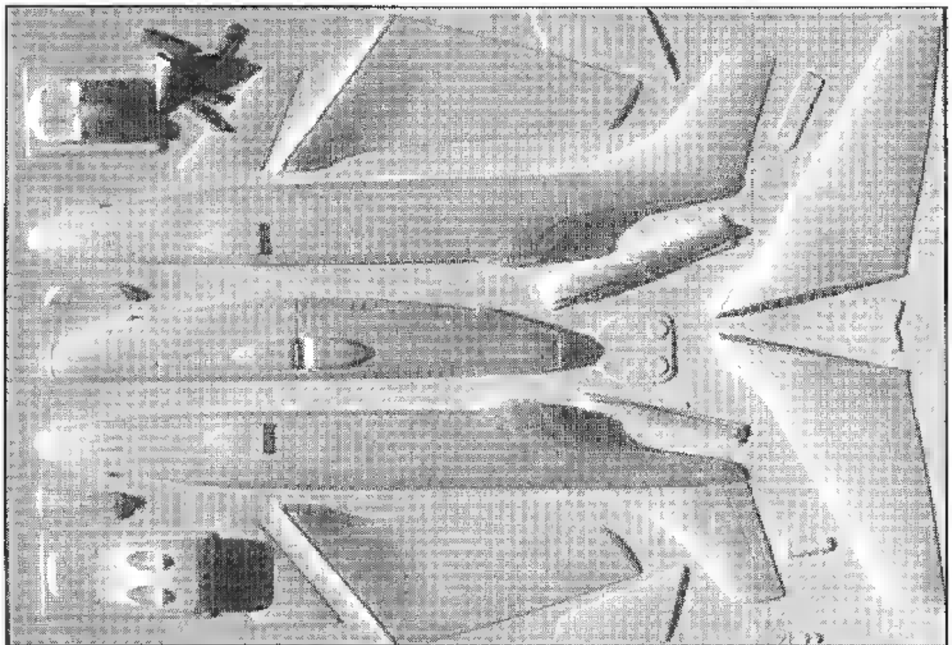
Lindberg's XF-88 model kit was originally released in the early 1950s box seen above. Like most of their early kits, it was a crude approximation of the real thing. This was largely due to the subject matter being prototypes for which engineering drawings were not released because the projects were still sensitive. At left is the front page of the '50s instruction sheet.

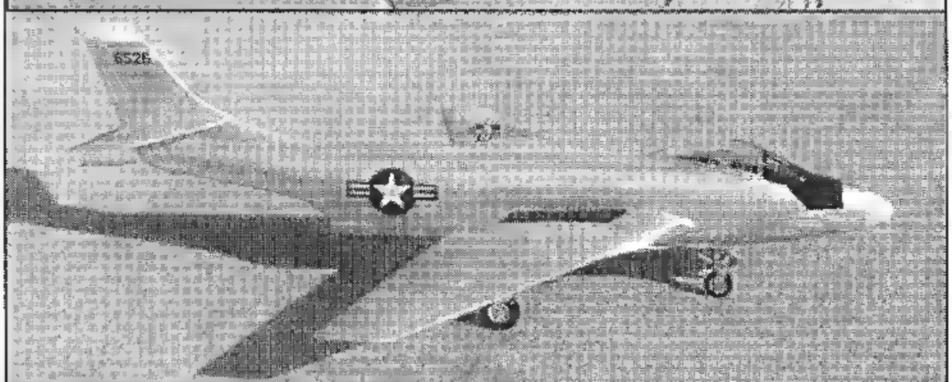
The kit had 45 parts, including movable controls and two jet engines that could be viewed through a trap door which opened above the left fuselage side national insignia. A pilot figure was included, along with a two-piece canopy which allows for the open canopy shown at right. The bulbous tip tanks are optional, with alternate wing tips to be used in their place. The tip tanks were rarely used on the real aircraft and were therefore left off the model at right. None of these early kits had nose or main gear wells molded into their fuselage and wings.

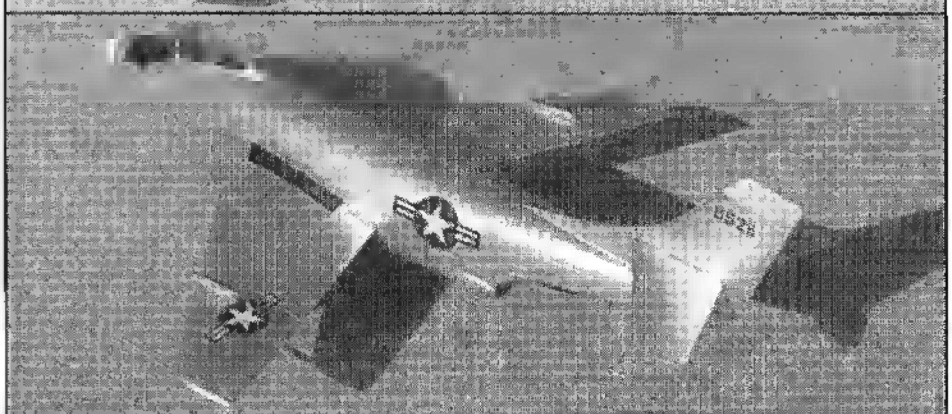
The kit has been re-released a couple of times since the 1950s, the most recent being in the box at right, which was issued in 1988. It was from this kit that the model at right was built. It was actually started in 1988, but remained uncompleted until this book project was undertaken.

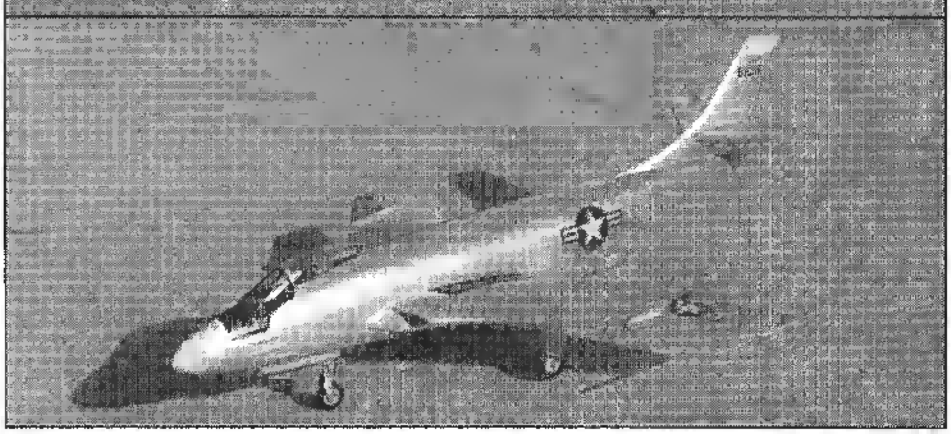

Lindberg
Classic
REPLICA
SERIES
XF-88 VooDoo
1:48 Scale Unassembled Plastic Model Kit

MAINTRACK MODELS VACUFORM 1/72 SCALE XF-88 VOODOO







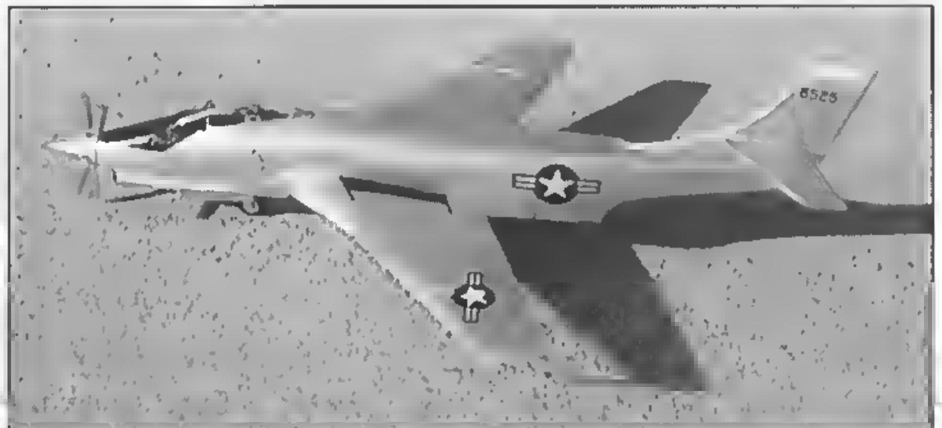


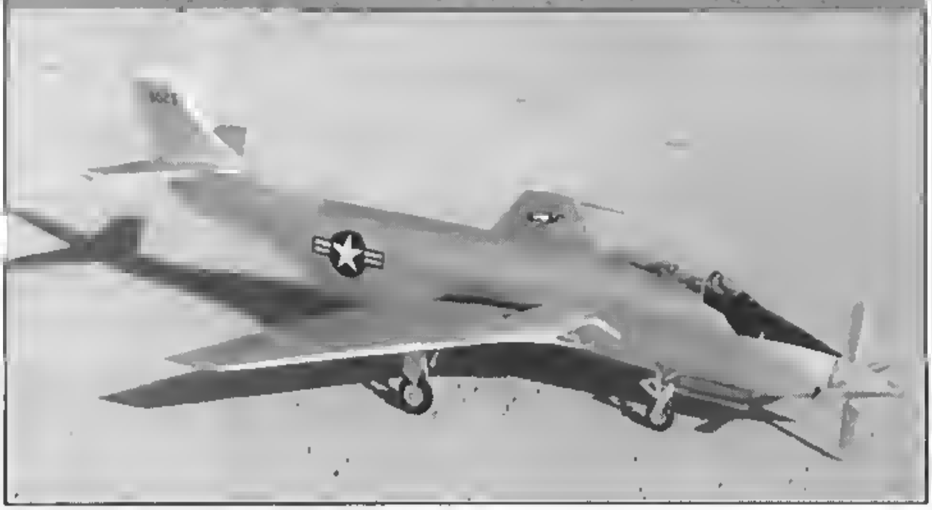
Maintrack Models has produced an extensive line of vacuform models with white metal gear and detail parts of American experimental and prototype aircraft. Their XF-88 kit comes with a bonus in that it can be built as either prototype without afterburner, or with the McDonnell developed short burner cans or as the XF-88B supersonic propeller test bed used by NACA.

Although I usually enjoy building vacuform kits, this kit almost proved my match. Due primarily to pilot or operator error, I had a hard time getting it right! My major difficulty was in grafting the XF-88B forward fuselage onto the original XF-88 fuselage. I had sanded down the two different fuselage halves to different heights, which required extensive body putty to correct. Further problems were encountered when I tried to install the nose landing gear wheel onto the nose strut/fork. I snapped the fork off where it joins the strut. Then, when building the XF-88A, I repeated this error and broke the second one too. A third area of the construction which gave me a major problem was the aft under-fuselage plug for the jet exhaust area. Two plugs come with the kit; one for the original non-afterburner equipped XF-88 and one for the afterburner equipped XF-88A and XF-88B. Much more time was spent trimming, fitting, puttying and sanding than was reasonable. A forth area of difficulty for which no easy solution was found was the installation of the mini main gear doors, which sit almost horizontally above the main tires when the gear is down (see photos pages 10, 14, and 24). In fact, I did not even install these on the review models.

The kit itself was not without fault. The main issue was the quality of finish of the surface plastic. This has usually been good to excellent on previous Maintrack kits, but was poor on both examples I used to build the review models seen here. It was more like the old Airmodel kits. Another problem was the cockpit. The kit provides a white metal ejection seat of a

MAINTRACK MODELS VACUFORM 1/72 SCALE XF-88B



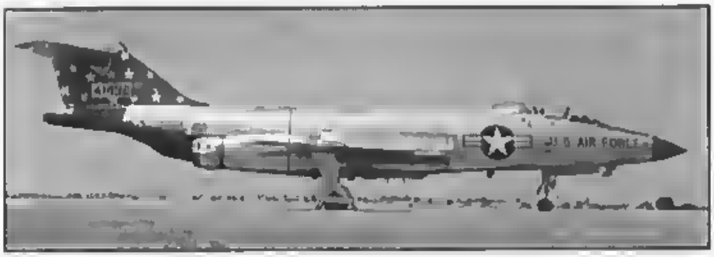


much later Martin Baker variety, instead of the simplified early McDonnell seat shown on page 48. Additionally, no provision, either in vacuform or in white metal, was made for the instrument panel or its hooded area under the windscreen. The third issue was that insufficient protection was provided for the white metal propeller, which arrived broken in each kit.

On the plus side, a good set of instruction drawings are provided as well as a very good set of white metal detail parts. Additionally, the vacuform canopy fits well and is crystal clear. The kit comes with decals for all three versions (XF-88, XF-88A, and XF-88B).

Even with the difficulties I experienced, I thank Maintrack for investing in this important example of late 1940s aviation technology.

McDONNELL'S SECOND VOODOO, THE F-101



At left top, F-101A #12 on 12-23-55. (via F. Roos) Upper left, 81st TFW F-101A in 1961. (via F. Roos) At left, F-101C. (via F. Freeman) Below left, 363rd TRW F-101C in 1966. (J. Sullivan via F. Roos) Below left, 29th FIS F-101B in 1966. (A. Swanberg via F. Roos) Bottom left, Canadian CF-101B. (via F. Roos) Above top, 17th TRS RF-101A. (via F. Roos) Above, 31st TRTS RF-101A on 8-14-70. (J. Sullivan via F. Roos) Below, RF-101C. (via F. Freeman) Below, RF-101B in 1976. (via F. Roos) 165th TRS RF-101H on 7-31-69. (P. Stevens via F. Roos)